Development of a process model for the design stage of building projects

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Signature ...J. Poon...
Date...12. NOV. 2001.....

Dedication

This work is dedicated to my family, especially my parents and my sister, Crystal

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Abstract

The aim of this research is to develop a CONstruction Best Practice System (CONBPS) which reflects the management of the process on a building project. CONBPS focuses on projects which use the traditional procurement strategy and JCT 80 standard form of contract.

Firstly, a theoretical construction plan of work has been developed for the whole design and construction cycle. This model clearly states the sequence of construction activities. Besides, it also identifies the roles and responsibilities of the major parties on the building team and the issues within the project cycle, which can prove critical to project success.

The theoretical framework is the inputted information for the prototype of CONBPS. Because of financial and time limits, the development of the computerised system focuses on the design stage. It is presented in an expert system, which provides interim and final reports based on the answers of the users. The reports are used to advise the participants on the success factors that they have ignored and to which aspects they should pay more attention.

CONBPS has been tested by a major survey and a two-stage evaluation process. The system has been updated after receiving the comments from practitioners. Both the theoretical framework and the user interface have been updated.

The first amendment on the theoretical framework concerned the roles of the parties. Apart from the major party for the activities, the participants who should provide support are identified in the framework. The second amendment related to the activities. Certain activities were classified in a hierarchy. Some activities, like cost management were in a major section with sub-headings, including cost control, cost advice and cost estimates etc.

On the 'interface' front, more functions were added. These functions included 'go back to the previous activity', 'running the construction activities in parallel', 'jump to specific activity', 'allowing the system to continue even if the user has not finished the previous activity', 'record the previous answers', 'allowing the participant to look at their own roles and activities only', 'connect the system to other software', 'add the on-line help function' and 'provide user code for each participant' etc. The aim of adding these functions was to facilitate the user and to assist the user in learning from the experience of past projects.

The targeted users of this system are project managers, construction participants, and any parties who are interested in understanding the construction process. Besides, the people who need to sort out the claims issues in construction projects can also use this system so as to check the appropriateness of the work sequence. Also the beginners of construction project can use this system as a 'teaching tool' for familiarisation with the construction process.

The major finding of this project has been the development of a final version of the expert system – CONBPS which has been updated incorporating comments from practitioners.

Owing to financial and time limits, the final version of CONBPS has focused mainly on the inception stage. The theoretical framework of the finalised CONBPS not only reflects the sequence of construction activities, but also identifies the major/ associated parties in the building process. Moreover, the activities are classified into hierarchical in order to facilitate the understanding of users.

On the system interface, it has also incorporates many user-friendly functions, including providing introductory screens for explaining the operations of the system, allowing users to simply choose an icon for answering each question, supplying interim and final reports and providing on-line help functions.

Acknowledgement

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Chapter 1

Introduction

1.1 Introduction

There are many criteria for evaluating project success; time, cost and quality being the most widely acceptable (Atkinson, 1999). A newly identified measurement of project success is the level of achievement of the objectives of the project parties (Belassi and Tukel, 1996).

De Wit (1988) stated that the 'project is considered as an overall success if the project meets the technical performance specification and/ or mission to be performed, and if there is a high level of satisfaction concerning the project outcome among the key people in the parent organisations, key people in the project team and key users or clientele of the project effort' (p. 165).

Baker et. al. (1988) further consolidated this argument and made a similar definition of project success. 'If the project meets technical performance, and/or mission to be performance, and if there is a high level of satisfaction concerning the project outcome, among key people in the parent organisation, key people in the client organisation, key people on the project team, key users or clientele of the project, the project is considered an overall success' (p. 902).

The final decision-maker on whether the project is a success is the client (Boyd and Kerr, 1998; Latham, 1994; Munns and Bjeirmi, 1996). The importance of the client has been identified in a number of reviews and reports. Some relevant quotations are given below:

- Flanagan (1981) stated that 'the important party within the construction industry is the client. Building is about getting it right for the client because he is the only man who matters at the end of the day' (Building, 1981: p. 29).
- Sir Michael Latham (1994) stated that 'clients are the core of the process and their needs must be met by the industry' (p. 3).
- Boyd and Kerr (1998) stated that 'the recent doctrine of being 'client-focused' has elevated the role of the client in the property and construction industry to a God-like position' (p. 88).

It can therefore, be concluded that 'the client's satisfaction is the most important criteria for project success'.

Numerous researchers have mentioned that value for money is the ultimate measure of client satisfaction. The concept of value for money is defined as 'the relationship between cost and quality' (Kim, 1998). In other words, the determinant of success is unchanged.

According to the findings of the survey prepared by the Construction Client Forum, the performance of the construction industry is not satisfactory (Ridout, 1999).

This survey found that fifty-eight percent of respondents experienced programme overruns on their projects with the length of delay averaging forty-eight days from the anticipated completion to the actual finishing date. Delays were also experienced at the front-end of the project with construction work starting on average fifty-three days behind schedule (ibid.).

On the budget front, clients were also critical of the industry's inability to keep to the agreed contract budget, with thirty-two percent of projects exceeding the agreed sum (ibid.).

When defining 'quality', there are many aspects to be considered as measures of quality. Absence of defects can be seen as one of the measures of achieving quality. Six percent of clients experienced major defects that affected handover substantially. Twenty-four percent identified one or two defects that caused slight delays and fifty-seven percent experienced a few defects. The average delay to respondents who reported one or two defects was four weeks, while those who suffered from major defects had their handover date pushed back by nearly eleven weeks (ibid.).

Apart from this, clients are often dissatisfied with their projects and this situation has existed for over twenty years. Earlier research included Mackenzie (1979) managing director of Slough Estates who stated that 'I believe that the industry's objective is to satisfy my needs but it is failing to do so' (Mackenzie, 1979: p.22). His criticism focused on the aspect that the building industry failed to deliver the goods on time, and at a reasonable price (ibid.). Sir Michael Latham's recent report (1994) also stated that 'the clients do not always get what they ask for and the level of client satisfaction in the construction industry is lower than the motor industry' (p. 11). Improving performance to satisfy clients is still the focus of a number of post Latham reports (e.g. CCF, 1998; CIB, 1996, 1997; Egan, 1998). Sir John Egan also expressed his 'deep concern that the industry as a whole is under-achieving' (Egan, 1998: p.2) and 'the need to improve in construction is clear' (ibid. p.8).

1.2 Reasons for objectives

There are many reasons which cause under-achievement within construction projects. The two prime reasons are the temporary multi-organisational nature of a construction project and the inefficient construction process.

The backgrounds of the parties within the construction process is different, as they have different specialist skills, so it is very difficult for them to co-operate in an efficient manner. However, they need to work together temporarily within a construction project. Besides, the specialist role of each participant is unique and they often find it difficult to rationalise the whole procedure and understand the responsibilities of other parties (Carpenter, 1981; Low, 1998). Karhu and Lahdenpera (1999) support this argument, they stated that 'the various stages and activities of a construction project are interdependent, and thus any disturbances by one of the parties effect the activities of other parties. Due to synchronisation problem created by rigid professional divisions of responsibility and the one-off nature of construction projects, such disturbance creates a lack of time in the process and lower productivity of construction in general' (p.52). The British Property Federation survey in 1997 also expressed a similar argument; their survey pointed out that more than a third of major clients are dissatisfied with the performance of contractors and consultants (Egan, 1998).

The second reason is the inefficient construction process (Fowler and Gray, 1996; Low, 1998; Tucker and Ambrose, 1998) with the traditional procurement strategy subject to the most criticism (Carpenter, 1981; Franks, 1990; Guest, 1993; Hardcastle and Tookey, 1998; Tucker and Ambrose, 1998; Walker, 1995). The traditional procurement approach was the most popular strategy used in the past, with about fifty percent of the contracts (measured by value) based on traditional procurement in the 1990's (RICS, 1994 and 1996). The traditional procurement strategy was still the most popular procurement strategy when the author started this project. However, in the last few years, the Design and Build procurement strategy has become the most popular procurement strategy with the traditional procurement strategy the second most popular strategy within the building sector (RICS, 2000).

According to the survey prepared by RICS and Davis Langdon & Everest (RICS, 2000), forty four percent and twenty eight percent of contracts used traditional procurement in 1995 and 1998 respectively. On the other hand, thirty percent and forty one percent of contracts used design and build procurement strategy in 1995 and 1998. Management contract was the third most popular procurement strategy in 1998 and its percentage of use was only ten percent.

The nature of the traditional procurement method further exacerbates the problem within the construction team. In the traditional procurement method, the design and construction responsibilities are separated. The contractor is the party responsible for the construction but does not have responsibility or liability in the design process (Hiley and Khaidzir, 1999). From another point of view, the use of traditional procurement methods prevents effective communication between architects and contractors prior to the construction stages of projects, thus depriving architects of gaining valuable knowledge on buildability issues (Alkass et. al., 1996). Rwelamila and Ngowi (1996) further summarised the disadvantages of traditional procurement method. They stated that 'the traditional procurement system' (TPS) has been criticised for being unable to cope with the complexity and the dynamic nature of the current industry in allocating project resources. Consequently new procurement processes are being introduced and utilised as the panacea in dealing with the objectives of the project economic system ... TPS itself, contending that it is out of date, inefficient, expensive and does not adequately reflect an appropriate relationship between the client and the contractor' (p. 117).

This separation of the design and construction process tends to foster a 'them and us' attitude between the designers and contractors. This reduces the team spirit that is vital to the satisfactory conclusion of a building project. It further leads to the parties become less trusting of each other and becoming more self-interested (Hiley and Khaidzir, 1999). Therefore, some literature stated that 'it is clear that a long-term, determined development and control of the building process requires common and systematic concepts and interpretation of the various activities involved' (Karhu and Lahdenpera, 1999: p.51).

Developing a construction process model, which clearly identifies the roles and responsibilities of the major parties on the building team and identifies the key issues within the project cycle, which can prove critical to project success, is therefore necessary. The author has developed a computer driven process model as an aid to improving the management of the project process. The system called the CONstruction Best Practice System (CONBPS) is a process model which focuses on the traditional procurement strategy as this is still a popular procurement strategy but at the same time subject to most criticism.

1.3 Aim and objectives

The primary aim of this research is to develop a construction process expert system in order to improve the management of the construction process and thus achieve a successful building project. This system focuses on projects which use the traditional procurement strategy, as it is the procurement strategy which is still one of the most popular but at the same time also subject to most criticism. Besides, it focuses on the JCT 80 standard form of contract, this is because the JCT 80 form (in all its variants) still remains the most commonly used form of contract for the procurement of building work in the United Kingdom. In 1998, ninety one percent of all contracts employed one of the JCT standard forms (RICS, 2000). Furthermore, the system focuses on a particular version, which is 'with quantities version' which is used for traditional single-stage tendering procedures (Seel, 1984). The 'with quantities version' is the most popular form in both the private and local authority editions (RICS, 1994, 1996 and 2000).

In 1998, an updated JCT standard form of contract was introduced. The JCT 98, in all forms, retains the style of JCT 80, it is an update only, not a complete make-over of the previous version (Ndekugri and Rycroft, 2000). The reason for introducing the JCT 98 was to incorporate the amendments which have been announced between 1983 and 1998. There were 18 amendments (22 issues) which were announced during this period. The most significant changes included (1) introduction of the adjucator, (2) advice to use 'activity schedule' instead of Bill of Quantities as a method for cost control, (3) introduction of the role of the employer's representative, (4) amendment on the method of valuation of variations and (5) requirement to give more information to the contractor (JCT, 1998).

The developed system was designed based on the JCT 80 standard form of contract. The JCT 98 was announced after the start of this project but in the end there were no fundamental changes between JCT 80 and JCT 98.

Because of financial and time limits, this project has developed the theoretical framework for the whole construction cycle. However, the computerised system focuses on the design stage, this is because the early phases of projects are often considered to be crucial, as this is where the most important decisions are taken. The conceptual stage of a construction project is a vibrant, dynamic and creative period. The ideas about the nature of the project, the requirements and desires, and potential solutions are generated at this stage. In other words, within this stage there exists a great potential for reducing the project cost and increasing customer satisfaction if careful decisions have been made (Josephson, 1999; Macmillan et. al., 1999 and 2000). However, this period can also be disorganised and even chaotic; there are many uncertainties about the project and the risks are high. The unconstructable nature of the design is often the cause of many contractual claims (Aouad et. al., 1998). Unfortunately, previous research emphasised the construction phase with little research focusing on the conceptual phase (Austin et. al., 2000).

This developed model clearly identifies the roles and responsibilities of the major parties on the building team and identifies the issues within the project cycle, which can prove critical to project success. The targeted users of this system are project managers, construction participants, and any parties who are interested in understanding the construction process. Besides, the people who need to sort out the claims issues in construction projects can also use this system so as to check the appropriateness of the work sequence. Also teachers and students of construction management can also use this system as a 'teaching / learning tool' in order to better understand the construction process.

The principal research aims will embrace the following objectives

1. To develop the theoretical construction plan of work. Apart from identifying the essential activities for finishing a construction project, this project also considers the activities which are concerned with modern construction management including risk management, value management, total quality management, safety management, design management, environmental management, partnering, benchmarking and constructability
2. To develop the framework which clearly identifies the roles and responsibilities of two major parties in the construction team
3. To develop the framework which states the sequence of construction activities
4. To identify the construction activities under the criteria of time, cost, quality and safety
5. To identify the critical gateways (or hotspots) within the project cycle
6. To identify the critical success factors for the construction process
7. To develop an expert system for modelling the construction process at the design stage

Deriving from the aims and objectives, the hypothesis for this project is 'to investigate the viability of developing a computer driven process model as an aid to improve the management of the construction process during the design stage with particular reference to lump sum tendering'.

1.4 Methodology

As with most research projects, the first task was to define the problem area and the proposed method of solution. Realising the broad nature of the topic and the many possibilities of approach, the scope of the research had to be limited to the issue of incorporating success into the building process.

Having defined the problem, the methodology can be classified into ten stages:

1. Desk based study and literature review
2. Evaluation of information and pilot survey
3. Developing the prototype expert system
4. Interview with practitioners
5. Analysing the findings and incorporate them into the system
6. Developing an updated system
7. Validation of the system
8. Verification of the system
9. Developing a finalised system

1.5 Structure of thesis

The structure of thesis is listed as follows:

Chapter 2: Review of concept of success in construction

This chapter examines the review of success in construction. Firstly, it reviews previous research into identifying success and failure factors on generic projects. It also identifies the success and failure factors on construction projects. Afterwards, it identifies the success and failure factors of construction process. Finally, there is a review on success criteria and the chosen criteria for a construction project will be stated.

Chapter 3: Classification of process modelling research

This chapter investigates different types of construction process models.

Chapter 4: Review of process modelling methods

This chapter studies various modelling methods for the developed construction process models.

Chapter 5: Theoretical framework of construction best practice system (CONBPS)

This chapter highlights the theoretical background/ foundations of this research. It examines the reasons for focusing on the conceptual design stage, choosing of criteria, roles and responsibilities of construction participants and the development of the new construction process model. Finally, the theoretical framework of CONBPS has been described.

Chapter 6: Development of CONBPS prototype

This chapter examines the definition and concept of an expert system, the suitability and the early applications in the construction industry. Besides, the development of the CONBPS prototype will also be discussed. The issues which will be discussed include: development tool, knowledge acquisition process, knowledge representation and the operation process.

Chapter 7: Research methodology

This chapter illustrates the methodologies adopted to elicit the information for CONBPS. Details are provided of the research instruments devised to obtain such information.

Chapter 8: Research findings

This chapter reports on the research findings, which includes the findings from the pilot study and the major survey. With regard to the findings of the major survey, it covers both the overall practitioners' comments and comparison among different disciplines.

Chapter 9: Development of updated CONBPS

This chapter summarises the development of updated CONBPS. First, it will explain the condition of use. Following this is the description of the amended theoretical framework. Finally is the discussion on the structure of the updated CONBPS. The aspects which will be of concern include the added functions, the knowledge representation structure and the operating process.

Chapter 10: Evaluation of CONBPS

This chapter evaluates the use of CONBPS. The evaluation process includes verification and validation. The concepts of evaluation and different approaches for the evaluation will be discussed. Afterwards is the discussion on the comments on the evaluation process. Ultimately, the final version of CONBPS will be presented.

Chapter 11: Conclusion and future work

This chapter summarises the conclusion, advantages and limitations of CONBPS. Also, the contribution of this research is stated. Finally, the recommended areas for future research are also highlighted.

Chapter 2

Review of concept of success in construction

2.1 Introduction

There is a proliferation of research on the subject of 'construction project success' written over the past few decades. The literature pertains to the achievement of success on a wide range of projects, either in a generic sense or related to particular areas. It appears that researchers attempting to understand construction project success could benefit from some of the work using an organisational theory perspective. Some of the articles discussed in this chapter deal with project success in a general project management perspective but are also felt to have direct application to understanding construction project success.

Several aspects have been widely discussed in the previous literature, which include definition of project success, factors for causing success or failure of project and success criteria. The definition of project success has been discussed in section 1.1, and it will not be repeated in this section. This chapter will first review the literature about identifying success and failure factors in the general project management perspective. Afterwards, it focuses on reviewing the success and failure factors for construction projects. The third part is the identification of success and failure factors for the construction process. Finally, there is a review on the success criteria for a construction project and identification of success criteria for the construction process.

2.2. Literature review of success and failure factors on general project management perspective

Identifying success factors for generic projects has been a very popular topic for researchers. There has been a vast amount of research undertaken in order to identify the success factors on generic projects. Hayfield (1979) was the first person who identified the success factors on generic projects. Based on a theoretical review, he classified the success factors into macro and micro factors. The macro factors included formulation of project policies, framework of project organisation, selection of key personnel, management control and management of information. The micro factors included definition of project, efficient manner of project execution, comprehension of project environment and selection of organisation realising the project.

DeCotiis and Dyer (1977) undertook twenty patterned interviews with the representatives in a cross section of the Technical Staffs Division of a major US company. They targeted respondents who had recently been involved in one or more projects. The focus of the interviews was the interviewees' perception of the critical aspects of project performance and its determinants. After finishing the interviews, they identified 12 determinants of project performance and classified them into three areas. The first area is 'external environment and relations'. The related factors included (1) management support, (2) inter-organisational relations, (3) sponsor relations, (4) transfer management, (5) planning and stability of specifications and designs; the second area is 'functional organisations relations', the related factors include (6) project leader-functional manager relations, (7) clarification of the project leader's role; the last category is 'internal operations', the factors consisted of (8) project members' skills and co-operation, (9) communication, decision-making and personnel utilisation, (10) planning and scheduling, (11) control procedures and (12) leadership. They provided the detailed description and definition of these factors in their article.

One of the first efforts to classify success factors was carried out by Schultz et. al. (1987). They classified factors as strategic or tactical. These two groups of factors affect project performance at different phases of implementation. The strategic factors include such items as 'project mission', 'top management support' and 'project scheduling' whereas the tactical group consists of factors such as 'client consultation', 'personnel selection' and 'training'. In their follow-up work, Pinto and Slevin (1989) identified success factors and their relative importance for each stage of a research and development project life cycle. Finally, in a similar study by Pinto and Prescott (1988), the relative importance of each group (tactical versus strategic) over the project life cycle was analysed. It was found that the relative importance of success factors varies at different stages of the project's life cycle, depending on the measurement of success used. When external success measures are employed, planning factors dominate throughout the project life cycle.

There are also several research projects identifying the elements which may affect the success of a project. Larson and Gobeli (1989) and Might and Fisher (1985) identified the elements which influence the project structure. Might and Fisher (1985) confirmed that the success of development projects varies according to which project management system is used and the project structure has a significant effect on success even when other determinants are considered. They identified that 'clearly defined objective' is the strongest and most consistent predictor of project success and functional organisational is an inferior means for managing a development project. The balanced matrix appears to have an advantage in controlling cost while the project matrix and project team were better equipped to meet schedule.

Might (1984) and Thrush et. al. (1987) identified the elements which influence control. Thrush et. al. (1987) compiled the interview response from designer to owners and identified 21 findings which are related to project control. They classified the headings into five groups which included findings related to organisations, planning, progress and performance measurement, control and owner's impact on project control.

Hensey (1991) identified 12 essential success factors that will help make planning efforts worthwhile by producing useful results more often. These essential success factors addressing the role of planning, planning the planning, the planning group, different talents of planners, advance preparation work required, focusing on a few key results areas, developing carefully chosen strategic objectives, using planning as the ideal opportunity for management team development, assigning needed champions for change, communicating the plan to the staff and reviewing the plan from time to time for progress and results.

On the other hand, identifying failure factors is also not lacking in research. Avots (1969) was the first research on identifying failure factors. He identified the reasons for project failure which included (1) basis for project not sound, (2) wrong man as project manager, (3) lack of company management support, (4) inadequate defined tasks, (5) management techniques misused and (6) project termination not planned.

Table 2.1 is the list of a classification of literature in success/ fail factors in general project management literature. Tables 2.2 and 2.3 are the list of generic successful and failure factors.

Generic

Theoretical studies	*Empirical studies*
Asquith (1979/80) *	Anderson (1992)
Avots (1969) *	Baker et. al. (1988)
Baker (1988) *	De Cotiis and Dyer (1977) and (1979)
Barnes and Wearne (1993)	Gobeli and Larson (1986)
Cash and Fox (1992)	Larson and Gobeli (1989)
Hayfield (1979)	Might (1984)
Hughes (1986)*	Might and Fisher (1985)
Jonason (1971)*	Pinto and Slevin (1987)
Nicholas (1989)	Shenhar et. al. (1997)
Nutt (1989)	
Schultz et. al. (1987)	
Tuman (1993)	

* Failure factors and lesson learn from it

Table 2.1 A classification of literature in success / fail factors in general project management literature

Generic	Clear objective	Early extensive project planning	Project manager ability	Project team ability	Client involvement	Good team working relationship	Communication	Client consultation	Top management support	Good project management	Safety management	Information management	Control management	Availability of resources	Preliminary cost estimates	Project termination management	External environment	Risk management	Personal management	Innovation	Schedule duration urgency	Politics	Learning	Minimum start-up difficulties	Absence of bureaucracy	Use of IT	Single manager authority	Structural factors	Client acceptance	Feedback capabilities	Technical tasks	Trouble-shooting	Project champion	Training	Project organisation structure	System and procedures
Anderson (1992)			●																																	
Avots (1969)		●	●								●	●				●																				
Ayas (1996)				●		●																	●													
Baker et. al. (1988)	●	●	●	●									●	●	●									●	●											
Barnes (1991)																				●																
Barnes and Wearne (1993)	●		●	●														●																●		
Beale and Freeman (1991)	●		●	●			●		●					●				●																	●	●
Cash and Fox (1992)			●	●					●				●													●										
Clarke (1999)	●	●					●																													
Cox (1993)		●																																		
De Cotiis and Dyer (1979)	●	●	●	●		●	●		●				●																							
Garvin (1993)																						●														
Hayfield (1979)	●																																			
Hubbard (1990)									●	●			●														●									
Lackman (1987)													●																							
Larkin and Larkin (1996)							●																													
Larson and Gobeli (1989)																												●								
Might (1984)													●																							
Might and Fischer (1985)																												●								
Nicholas (1989)				●	●	●																														
Nutt (1989)	●	●	●	●	●	●	●		●				●	●																						
Pinto and Prescott (1988)	●							●	●																											
Pinto and Slevin (1987)	●	●	●	●	●		●	●	●		●	●	●	●					●										●	●	●	●	●			
Pinto and Slevin (1998b)																	●				●	●														
Rubin and Seeling (1967)			●																																	
Wideman and Victoria (1981)													●																							
Yeo (1993)																						●														

Table 2.2 Generic factors leading to project success

Generic	Ill-defined objective	Poor planning	Poor communication	Poor project manager	Cost overrun	Schedule overrun	Lack of supportive management	Project termination not planned	Project management techniques misused	Excessive control	Poor scheduling	Poor organising	Poor staffing	Poor directing	Poor controlling
Ashquith (1979/80)	●		●		●	●									
Avots (1969)	●			●			●	●	●						
Barnes and Wearne (1993)		●	●							●					
Gobeli and Larson (1986)		●									●	●	●	●	●
Hughes (1986)			●						●						

Table 2.3 Generic factors leading to project failure

2.3 Literature review of success and failure factors on construction projects

Jaselkis and Ashley (1988) identified the determinant factors in order to achieve budget, schedule and outstanding project performance. They identified 27 factors and grouped the success factors into four headings, which included project manager's capabilities, experience and authority, the stability of project team, project planning and control effort. After analysing the information from 78 projects by logistic regression analysis, they identified '*reducing team turnover*' and '*program constructability*' as the two key factors for achieving project success on construction works..

Jaselkis and Ashley (1991) investigated the impact of the project team, planning and control efforts as they relate to achieving 'overall' project success, better than expected schedule performance and better-than-expected budget performance. As in previous research, this research also used the discrete choice model as the analysis method. The results demonstrated that the key success factors affected the project outcomes differently. For example, 'increasing the number of budget updates' has more of an impact on achieving better budget performance than it does on achieving better schedule and overall project performance. 'Implementation of a constructability program' seems to have a significant impact on achieving overall project success and better schedule performance – especially on fixed-price contracts. 'Reducing team turnover' has more significant impact on improving budget performance than it does in achieving better schedule or overall project performance.

Chua et. al. (1997) used another method to analyse the data derived from Jaselkis and Ashley (1988)'s research. They used neural networks as the analysing method focusing on budget performance only. The final model identified eight factors which were most important for budget performance. These eight factors included; (1) number of organisational levels from the project manager to the craft workers, (2) amount of detailed design completed at the start of construction, (3) number of control meetings during the construction phase, (4) number of budget updates, (5) implementation of a constructability programme, (6) team turnover, (7) amount of money expended on controlling the project and (8) the project manager's technical experience.

Kog et. al. (1999) replicated Chua et. al. (1997)'s research, but they aimed at identifying the key determinants for construction schedule performance. Like Chua et. al., (1997)'s research, they also used the data derived by Jaselkis and Ashley in 1988. The key determinants included (1) time devoted by the project manager to a specific project, (2) frequency of meetings between the project manager and other project personnel, (3) monetary incentives provided to the designer, (4) implementation of constructability program and (5) project manager experience on projects with a similar scope.

Chan and Kumaraswamy (1997) have determined and evaluated the factors causing delays on construction projects in Hong Kong. They have identified 83 hypothesised delay factors and grouped them into eight categories. The main reasons for delay were analysed and ranked according to different groups classified on the basis of (a) role of the parties in the local construction industry (i.e. whether clients, consultants and contractors) and (b) the type of projects. They collected data from 167 local construction organisations and analysed it by using the relative impact index method in order to rank the determinant delay factors for different types of construction projects. The results indicate that the five principal and common causes of delays are: (1) poor site management and supervision, (2) unforeseen ground conditions, (3) low speed of decision making involving all the project team, (4) client initiated variations and (5) necessary variations of works.

Dissanayaka and Kumarawamy (1999a) and (1999b) have also done research on identifying the critical reasons relating to time and cost performance on the Hong Kong building projects. The results suggest that procurement sub-systems variables are less significant than the non-procurement related variables in predicting time and cost performance levels on Hong Kong building projects. The procurement sub-systems include work packaging, functional grouping, payment modality, selection methodologies and standard sets of conditions of contracts. The non-procurement variables include project characteristics, procurement system, project team performance, client/ client characteristics, contractor characteristics, design team characteristics and external conditions. The finding of this research is similar to previous research instigated by Walker (1995) and Rowlinson (1988).

Apart from studying the determinants for particular success criteria of construction projects, examining the success factors for a specific area has also been a popular topic.

Lim (1993) and Kumaraswamy (1997) studied the critical issues for productivity. Lim (1993) focused on studying the influence of managers', supervisors' attributes and attitudes of site workers on construction productivity. Kumaraswamy (1997) formulated a hierarchy of productivity indictors in order to measure efficiency in a given scenario.

Dierkmann and Girard (1995) identified the factors leading to contract disputes. This project identified the effect of different project characteristics, which included people, process and project aspects, on the occurrence of contract disputes. The finding of this work was based on logic regression analysis on the frequency and severity of disputes on 159 construction projects. The results concluded that all three issues played a role in influencing the likelihood of contract disputes, but the 'people' issue holds the key to avoiding contract disputes.

There has also been research which identified the success factors that influence the performance of certain procurement strategies. Tiong et. al. (1992) did the first research in this area. They identified the critical success factors in winning build-operate-transfer (BOT) contracts. Morledge and Owen (1998) and Cheng et. al. (2000) identified the critical success factors for Project Finance Initiative (PFI) contracts and partnering projects respectively. The more recent research on this area is prepared by Chan et. al. (2001). They identified a set of project success factors for design and build (D&B) projects and examine the relative importance of these factors on project outcome. They have identified the six success factors for D&B projects, which include project team commitment, contractor's competencies, risk and liability assessment, client's competencies, end-users' needs and constraints imposed by end-users.

Evaluation related to the construction parties and the study of their influence on the project success is also another favourite topic. Kometa et. al. (1995) researched on pre-contract client evaluation. They found that clients who conducted an internal audit of their organisations before embarking on the briefing process, would generally have a higher level of success. Hatush and Skitmore (1997) researched into the pre-qualification for contractors. The aim of their research was to investigate the perceived relationship between 20 contractor selection criteria (CSC) currently in use and project success factors (PSFs) in terms of time, cost and quality involving a sample of eight experienced construction personnel.

There has been a lot of research on construction management focusing on identifying success factors. These publications include research on the overall construction project or on a particular segment of a construction project.

Ashley et. al. (1987) did a comprehensive empirical study on identifying success factors for construction projects. They identified 46 success factors for construction projects and grouped them under five headings, which include (1) management, organisation and communication, (2) scope and planning, (3) controls, (4) environmental, economic, political and social and (5) technical. After analysing the data, they identified the most important success factors for construction project which included (1) planning effort, (2) project team motivation, (3) project manager goal commitment, (4) scope and work definition, (5) control systems and (6) project manager technical capabilities.

Apart from theoretical and empirical studies, there are several researches which identify the success factors by studying the experience on real-life projects.

Morris and Hough (1987) did the first research in this area. They studied eight large complex projects which included the Channel Tunnel, Concorde, the Advanced Passenger Train, the Thames Barrier, Heyshame Nuclear Power Station and the AGR Programme, the Fulmar North Sea Oil Field, the Computerisation of PAYE and Project Giotto. After studying the experience of these projects, they identified 47 success factors and classified them in the following headings: project objectives, technical uncertainty, innovation, politics, community involvement, schedule duration urgency, financial contract legal problem and implementation problem.

Bedelian (1996) has done similar research but he focused on UK construction projects. He studied the experience of several construction projects in the United Kingdom, like Glasgow Airport, St-James Interchange and Rolls-Royce Test Bed 57. Finally, he drew the success factors as (1) clarity of tender documents, (2) good client/ contractor relationships, (3) clear design brief with minimal subsequent changes, (4) time given to develop the design, (5) early and detailed design and planning and (6) value engineering.

On the other hand, Skyes (1986) has drawn out the distinctive characteristics of failure in construction project by his experience learned from participating in large international construction projects. These characteristics include the large number of participants and the long duration of the project. If the project has a long duration, the project will face greater risk and it is more difficult to foresee the future.

Distinguishing the characteristics of the success factors and the issues which influence the success factors for the construction project has also been a popular topic. Kothari (1986) and Chan (1992) identified the characteristics of the project manager in construction management. Kothari (1986) identified the characteristics of a successful project manager as: leadership, technical knowledge and experience, communication, planning and organisation, motivation and personality. Chan (1992) identified the additional characteristics of co-ordinating and controlling.

Chauhan and Chang (1989) did surveys in various Asian Regions including Hong Kong, India, Korea, Singapore, Taiwan and Thailand. After analysing the received 100 questionnaires, they identified 13 factors which influenced the performance of project team members. They classified these factors into three headings which included project related, environmental related and management related.

Table 2.4 is the list of a classification of literature in success/ fail factors for construction projects; tables 2.5 and 2.6 are the list of successful and failure factors for construction projects.

Construction

Theoretical studies	*Empirical studies*	*Experience from real project*
Archibald (1976) *	Ashley et. al. (1987)	Bedelian (1996)
Atkin and Flanagon (1995)	Chan (1992)	Cole (1999)
Bentley and Raftery (1991)	Chauhan and Chiang (1989)	Graham (1988)
CRT (1995)	Gobeli and Larson (1986)	Jolivet and Batingnolles (1986)
Khachaturi+A143an and Gnaedinger (199	Ireland (1985)	Kothari (1986)
Maloney (1990)	Jaselkis and Ashley (1988)	Morris (1986)
Munns (1995)	Rowlinson (1988)	Morris and Hough (1987)
NEDO (1985)	Walker et. al. (1997)	Skyes (1986)
Parfitt and Sanvido (1993)		

* Failure factors and lesson learn from it

Table 2.4 A classification of literature in success / fail factors in construction project management literature

Construction	Clear objective	Early extensive project planning	Clear project brief	Project manager ability	Project team ability	Client involvement	Good team working relationship	Relation between client and project team	Communication	Client consultation	Top management support	Clear policy manual	Good project management	Safety management	Information management	Control management	Clarity of tender documents	Availability of resources	Preliminary cost estimates	Project termination management
Ashley et al (1987)	●	●		●	●									●		●				
Atkin and Flanagon (1995)			●				●		●					●						
Bedelian (1996)		●	●					●												
Belassi and Tuckel (1996)				●	●					●	●							●	●	
Bentley and Raftery (1992)	●	●			●				●			●				●	●			●
Chan (1992)					●															
Chan (1997)																				
Chua et al (1997)				●									●							
Cleland (1986)						●					●		●							
Cole (1999)							●													
CRT (1995)				●	●															
Gobeli and Larson (1986)	●	●			●	●			●		●				●	●				
Graham (1988)	●	●									●				●	●				●
Hai (1996)													●							
Ireland (1985)																				
Jaselkis and Ashley (1988)		●		●	●											●				
Jolivet and Batingnolles (1986)													●							●
Khachaturuan and Gnaedinger (1996)				●		●	●		●											
Kim (1999)																				
Kothari (1986)				●																
Mead (1997)															●					
Morris (1986)	●	●		●	●	●	●		●		●					●		●		
Morris and Hough (1987)	●																			
Munns (1995)																				
NEDO (1975)	●		●		●	●							●							
NEDO (1985)	●		●		●	●							●							
Owen and Martin (1986)									●											
Pocock et al (1997)							●													
Ratcliffe (1991)				●																
Rowlings et al (1987)	●	●				●	●				●	●								
Rowlinson (1988)	●	●		●	●		●								●	●				
Sandvido et al (1992)					●										●					
Thamhain and Wilemon (1987)							●													
Versau (1986)								●												
Walker et al (1997)	●	●		●		●			●					●		●			●	
Weng (1990)					●	●														

Construction	Selection of procurement option	Contracting documentation and management	External environment	Design management	Value management	Risk management	Cost management	Quality management	Program management	Financial management	Personal management	Material management	Innovation	No conflict	Community involvement	Schedule duration urgency	Financial contract legal problem	Implementation problem	Trust	Quick response to changes	Weather
Ashley et al (1987)			●	●		●															
Atkin and Flanagon (1995)	●				●																
Bedelian (1996)				●	●																
Belassi and Tuckel (1996)																					
Bentley and Raftery (1992)																					●
Chan (1992)																					
Chan (1997)																					
Chua et al (1997)																					
Cleland (1986)																					
Cole (1999)																					
CRT (1995)	●																				
Gobeli and Larson (1986)																					
Graham (1988)		●	●			●					●										
Hai (1996)																					
Ireland (1985)				●										●							
Jaselkis and Ashley (1988)																					
Jolivet and Batingnolles (1986)		●		●			●	●	●	●	●										
Khachaturuan and Gnaedinger (1996)																					
Kim (1999)												●									
Kothari (1986)																					
Mead (1997)																					
Morris (1986)				●									●		●	●					
Morris and Hough (1987)													●		●	●	●	●			
Munns (1995)																			●		
NEDO (1975)																					
NEDO (1985)																					
Owen and Martin (1986)																					
Pocock et al (1997)																					
Ratcliffe (1991)																					
Rowlings et al (1987)																				●	
Rowlinson (1988)		●		●										●							
Sandvido et al (1992)																					
Thamhain and Wilemon (1987)																					
Versau (1986)																					
Walker et al (1997)				●		●															
Weng (1990)		●	●																		

Table 2.5 Factors leading to project success on construction projects

Construction	Ill-defined objective	Poor project management	Poor planning	Poor communication	Poor project team	Poor control	Poor project manager	Conflict	Lack of resources	Unrealistic task	Many and rapid changes
Archibald (1976)	●	●	●			●	●	●	●	●	●
Louden (1995)					●						
Rowlings et. al. (1987)	●	●	●	●	●	●				●	●

Table 2.6 Factors leading to project failure on construction projects

2.4 Factors leading to success and failure of the construction process

After reviewing the success factors in the previous sections, several success factors relevant to construction process are identified and listed as follows:

2.4.1 Success factors for the construction process

Clarity/ Definition of project objective

- To state clearly what is the expected end-result, with the consultation of the related parties. Although each party might have different specific goals in mind for the project, they must spell out their common goals.
- To state the communicated and defined goal to all parties.
- To state the clarified time and cost objectives.

(Beale and Freeman, 1991; Bentley and Raftery, 1992; Clarke, 1999; Morris, 1986; Pinto and Slevin, 1987)

Scope of project

- To state the general direction and defining client's requirement.
- To present a clear design brief with minimal subsequent changes. A brief must be exacted and owned by the client at the highest (strategic) level within the client and project organizations.

(Atkin and Flanagan, 1995; Beale and Freeman, 1991; Bedelian, 1996; CRT, 1995; Pinto and Slevin, 1987)

Project manager

- The project manager is the key person in the project. The requirement of his skill is multi-dimensional, which includes interpersonal, technical and administratively.
- The most important element is that the project manager must clearly understand his role as a project leader. He should understand the extent that he needs to be involved, his defined authority and the amount of control he should exercise over personnel.
- Personality – the project manager must have an impressive personality so that team players, associates and peers look up to him and pay attention to his requests.
- Leadership – the project manager should have leadership skills and be able to apply competent and managerial skills. The project manager should have the ability to convince the other member of the group that the situation will be improved if they behave as suggested. He should also be able to make a decision if there is conflict between the parties.
- Organising – the project manager should be responsible for organising, selecting and defining the responsibilities of the project team.
- Co-ordinating – the project manager should identify interfaces between the activities of functional departments, subcontractors, and other project contributors.
- Controlling – the project manager should be responsible for monitoring progress, identifying problems, communicating the status of interfaces to contributors, initiating and co-ordinating corrective action.

- Motivating – the project manager should motivate the project team to perform their duties, and also convince the project team to co-operate with each other.
- Technical knowledge and experience – the project manger in a construction environment must posses good technical knowledge and experience, since most of the project is highly technical.

(Chan, 1992; DeCotiis and Dyer, 1979; Genega, 1997; Kothari, 1986; Pinto and Slevin, 1988a)

Project team

Commitment

- All participants must understand and be dedicated and strongly committed to achieve, maintain and fulfil project goals.
- All participants must be committed to the concept of project planning and control and must be able to put the concept into practice. They must understand the project management process, its purpose and values, and be committed to follow the steps and necessary procedures.

(Baker et. al., 1988; Barnes and Wearne, 1993; Nicholas, 1989)

Capability

- Possess adequate capability, including skill and experience.
- Retain appropriate interpersonal skills.

(Baker et. al., 1988; Beale and Freeman, 1991; Cole, 1999; Pinto and Slevin, 1987)

Co-operation

- Maintain a good working relationship between client, project team members and stakeholders.
- Sustain good working spirit.

(Atkin and Flanagan, 1995; Bedelian, 1996; Bentley and Raftery, 1992; Cole, 1999; DeCotiis and Dyer, 1979; Morris, 1986)

Planning

- Be prepared as early as possible, preferable before the construction work starts.
- Be prepared, with as much detail as possible, including during the design process and throughout its phases. Detail required includes individual action steps for project implementation, the responsible party if known and the technical standard required.
- It should be a realistic plan, it should plan the appropriate workload for the project team.
- Planning must be updated regularly in order to keep pace with the project development.
- Prepare to re-plan the job schedule to accommodate frequent changes on dynamic projects.
- Have detailed planning when approaching the time of termination of the project.

(Avots, 1969; Barnes and Wearne, 1993; Bedelian, 1996; Bentley and Raftery, 1992; Clarke, 1999; DeCotiis and Dyer, 1979; Hensey, 1991; Hughes, 1986; Morris, 1986; Pinto and Slevin, 1987)

Control

- Schedule control - the project management and superintendents should jointly agree on intermediate milestones and build the detailed schedule around them.
- Cost control - focus on tracking the money spent. This requires detailed actual costs, and one of the best monitoring aids is a plot of plan versus actual costs on a cash-flow curve, e.g. earned-value analysis system.
- Quality control - focus on ensuring the project reaches the agreed and designed level of quality, and it must be closely scrutinised during the entire process.
- The methods for performing control include regular meeting and day-to-day reports etc.

(Beale and Freeman, 1991; Bentley and Raftery, 1992; Cash and Fox, 1992; Chua et. al., 1997; DeCotiis and Dyer, 1979; Morris, 1986; Pinto and Slevin, 1987)

Appropriate size of work package

- Maintaining the project task into appropriate size and identify the relevant parties responsible for the task.
- Keep the level of staff appropriate for the amount of work that needs to be done.

(Avots, 1969; Clarke, 1999; DeCotiis and Dyer, 1979; Hughes, 1986)

Communication and information management

- Having good and adequate communication channels among the project team.

- Ensuring there is some way to manage the flow of information. The suggested methods of transferring information should include drawings, manuals, meetings and letters.

(Avots, 1969; Beale and Freeman, 1991; Bentley and Raftery, 1992; Clarke, 1999; Graham, 1988; Pinto and Slevin, 1987)

Top management support

- Provide the necessary resources, authority and power for performing the project.

(Beale and Freeman, 1991; Cash and Fox, 1992; DeCotiis and Dyer, 1979; Pinto and Slevin, 1987)

Environment

- Natural environment, e.g. weather, including temperature and heavy rain.
- Social environment, e.g. supply of labour and materials.
- Political environment, e.g. legal requirement requested by the regulatory authorities.

(Beale and Freeman, 1991; Belassi and Tuckel, 1996; Graham, 1988)

Health and safety

- Ensure there is the consideration of legislative health and safety measures.

(Atkin and Flanagan, 1995)

2.4.2 Failure factors for the construction process

Unclear project definition

- Unclear goals: unrealistic objectives, scope and plans; unworkable design and absence of direction.

(Avots, 1969; Gobeli and Larson, 1986)

Project manager

- Weak project manager: The categories include; no project manager was assigned when one was needed, project manager had a poor understanding of his/her job duties, reporting to the wrong part of the organisation and lack of support from the top management.
- Incompetent project manager: The manager who is poorly trained or inexperienced in project management.
- Poor leadership: This includes not giving direction, not paying attention to project needs and playing politics among managers.

(Archibald, 1976; Gobeli and Larson, 1986)

Project team

- Low commitment: Little or no motivation to do the work, a lack of participation in project activities, lack of co-operation and excessive, unresolved conflict. The essence of this barrier is that people are not willing to do the job.

- Lack of responsibility or accountability: The project team members do not clearly understand their responsibilities or they have excessive assigned responsibilities. Therefore, they cannot perform adequately.

(Gobeli and Larson, 1986)

Improper planning

- Unrealistic planning and scheduling.
- Inadequate or excessive work planning.

(Archibald, 1976; Barnes and Wearne, 1993; Gobeli and Larson, 1986)

Poor control

- Start the control procedure at a too late a stage.
- Excessive control.
- Lacking a control system.
- Not enforcing schedules or contracts.

(Asquith, 1979/0; Barnes and Wearne, 1993; Gobeli and Larson, 1986)

Poor schedules

- The schedules are too tight, unrealistic or impossible.
- Ignoring 'variations' in the schedule, for example, delay of work during Christmas time or a public holiday.
- Unable to meet the scheduled target.
- Unable to modify or update schedule so as to reflect project changes.

(Archibald, 1976; Gobeli and Larson, 1986)

Poor communication

- No defined communication method.

(Asquith, 1979/0; Hughes, 1986; Gobeli and Larson, 1986)

Company management unsupportive

- Lack of support from the parent company.

(Avots, 1969; Gobeli and Larson, 1986)

The identified successful factor for construction process will be part of the information stated in the reports in the updated CONBPS. The development of the updated CONBPS will be discussed in chapter 9.

2.5 Success criteria

Identifying the success criteria is a favourite topic among general and construction project management literature.

DeCotiis and Dyer (1977) first attempted to identify the criteria for success. They obtained the data by extensive interview of personnel staff in a US company and they analysed the content by subsequent factor analysis. They identified five performance dimensions which focused on business, engineering, concerns for resources use, human resource and scientific outcomes. Probably because they obtained the data from a sole company and this company engaged in the manufacture and marketing of highly sophisticated products for industrial and consumer use, the identified success criteria is quite unique and different from the other researches.

Baker et. al. (1988) have also done research in this area. After sampling over 650 project managers, the researchers concluded that project 'success' is something much more complex than simply meeting cost, schedule and performance specifications. They identified 'client satisfaction' as the most important criteria for project success. This opinion is confirmed by Pinto and Slevin (1988b) and Shenhar et. al. (1997), but they identified 'achieving objectives' as an additional success criteria.

Ashley et. al. (1987) prepared the first comprehensive study on identifying success criteria for construction projects. They identified 10 success criteria for construction projects, and divided them into important and less important criteria. The important criteria include budget performance, scheme performance, client satisfaction, functionality, contractor satisfaction and project management team satisfaction.

Rowlinson (1988) prepared another comprehensive list of measurement of success under the subjective and objective terms. He defined the three sets of measures that were used to measure performance: objective and absolutely measures; objectives, predictability measures and subjective measures of client satisfaction. He identified the measures which included predictability of budget, relative cost, predictability of scheme, relative speed, subjective assessments of quality and function and subjective assessment of time and cost performance.

Chan (1997) has reviewed six previous researches on identifying success criteria for construction projects He has concluded that success criteria should be classified as subjective and objective measures. The subjective measures of construction projects can include client satisfaction on cost, time, quality, functionality and overall performance as well as other key participants' satisfaction. The objective measures can include construction time, speed of construction, unit cost, time performance ratio, and percentage net variation over final cost.

Table 2.7 is the list of the success criteria for projects.

	Time	Cost	Quality	Client Satisfaction	Project team satisfaction	Safety	Functionality	Absence of claims and disputes	Minimise resources utilisation	Achieve objective	Effectiveness	Efficiency	Productivity	Innovation	Business performance	Technical performance	Personal growth experience
Generic																	
Baker et. al. (1988)	●	●	●	●	●												
Beale and Freeman (1992)	●	●	●														
DeCotiis and Dyer (1977)												●		●	●	●	●
Maloney (1990)			●								●	●	●				
McCoy (1986)	●	●	●														
Might (1984)	●	●	●														
Pinto and Slevin (1988a)	●	●	●	●													
Shenhar et. al. (1997)	●	●	●	●						●							
Construction																	
Ashley et. al. (1987)	●		●	●	●		●										
Chan (1997)	●	●	●	●	●		●										
Cheung (1998)	●	●	●					●	●								
Goldsmith (1986)						●											
Herbsman (1986)								●									
Ireland (1985)	●	●	●														
Jaselkis and Ashley (1988)	●	●	●			●											
Kumaraswany and Thorpe (1995)	●	●	●	●	●	●											
Lai (1989)	●	●	●														
Morris and Hough (1987)	●	●	●				●										
Rowlinson (1988)	●	●	●				●										
Sanvido et. al. (1992)	●								●								
Sidwell (1982)				●													
Sidwell (1984)	●	●	●	●													
Wuellner (1990)	●	●	●	●													

Table 2.7 Success criteria for both generic and construction projects

2.6 Reflection and conclusion

The identification of factors leading to success and failure has been a popular topic for both general project management and construction project management research in the past few decades. The research in factors leading to success has not only focused on a general perspective, but also on particular aspects, such as success criteria and the particular procurement strategy. The importance of this exercise has been to increase the awareness of the construction participants to what aspect they need to pay special attention; finally, it will increase the level of success on construction projects.

The information derived in this chapter will also be incorporated as part of the interim and final reports of the developed system.

Identifying the successful criteria has also been a popular topic. Although there is a variety of opinions of success criteria both on general projects and construction projects, several criteria re-occur in nearly all published literature. These criteria are 'time', 'cost', 'quality' and 'client satisfaction'. This research project focuses on the 'process'. By better understanding the process, the project team is able to deliver all these success criteria, i.e. achievement of project within time, within budget to required quality, thus ensuring client satisfaction. Furthermore, 'safety' will also be identified as additional success criteria for this project because it is a newly raised issue for the construction industry.

The success criteria is one of the major issues in the newly developed construction process model. The discussion of the development process will be further discussed in chapters 5 and 6.

Chapter 3

Classification of process modelling research

3.1 Introduction

The building process is a lengthy and fragmented process. Karhu et. al. (1997) defined the building process as 'involving all activities, tasks and roles of the participants, starting with the first initiative for realizing a building encompassing programming, design and construction of the building and ending with maintenance' (p.18).

The construction activities can be identified as value adding or non-value adding activities. Value adding activities are the activities which add value to the product during the process. Non-value adding activities are those activities that add much more cost than value to the process. Thus waiting for materials, waiting for instructions, rework and inspection is considered as non-value-adding activities for the construction process. The building cycle comprises a vertical and horizontal structure. The vertical structure is the sequence of the construction activities and the horizontal structure is the responsibilities of consultants for these construction activities (Ireland, 1985; Lahdenpera, 1995; Kagioglou et. al., 1999; Kartam et. al., 1997; Mohsini, 1989).

Because of the complications within the construction cycle, it is important to have a clear understanding of the process (Abeysinghe and Urand, 1999; Halpin, 1993). Besides, modelling the construction process is seen as a method for increasing productivity and improving quality and reducing defects (Egan, 1998; Finnemore et. al., 2000; Latham, 1994; Sarshar et. al., 1998).

The researchers in the forefront of the industry have recognised the importance of modelling and understanding the construction process in order to bring improved methods and technology to the industry (Halpin, 1993; Abeysinghe and Urand, 1999; Finnemore et. al., 2000). Rosenau (1996) notes a process model is 'an effective way to show how a process works'. Aouad et. al. (1999) enhanced the usefulness of the construction process model mentioned. They stated that 'a process model can be defined as a way in which the processes involved in the designing and constructing of a structure are re-arranged so as to produce a more efficient, effective and economical way of undertaking the design and construction of projects. Tangible benefits can be realised through wastage reduction, shortening the duration of projects or improving communication methods and channels' (p.139).

3.2 Necessity of process modelling

Modelling is a means of conceptualising some well-defined part of the real world. A conceptual model will show the structure of information in these 'mini-worlds'. Conceptual models provide formal definitions of the basic entities and relationship required to fully represent the information about the domain in the question. Modelling a system is a critical step for understanding and improving its performance. One can better understand how a system works once a model of that system has been analysed. Throughout this analysis, one can identify problems in the systems design and thus suggest a new design that will eliminate these problems. The ultimate goal of this modelling exercise is to improve the performance of the system (Kartam and Ibbs, 1996; Laitinen, 1998).

Construction is a process-based industry. In such an industry, it is important to have a clear understanding of the process. The researchers in the forefront of the industry recognised the importance of modelling and understanding the construction processes to bring improved methods and technology to the industry (Halpin, 1993; Abeysinghe and Urand, 1999; Finnemore et. al., 2000). Halpin (1993) explicitly mentioned this idea, stating 'we will witness an explosion of new and innovative construction-process technology. Since construction is a process-based industry, we must strive to improve our construction methods and processes. But in order to develop new processes, we must better understand the present processes, which are in place. Moreover, as stated earlier, innovation and process improvement require a framework or notation within which processes can be studied and improved' (p.423).

Apart from academic researchers, Latham (1994) and Egan (1998) mentioned that the lack of advanced management of the construction process is the cause of the poor productivity and quality of the construction industry, which are the fundamental problems of this industry.

Research into developing a model to reflect the building process has been a popular topic in recent decades. Within this chapter and the next chapter, a review of previous construction process models is undertaken. This chapter focuses on discussing different kinds of construction process models.

3.3 Regression model

A regression model is used to describe the model which has independent variables and a dependent variable, and sometimes, it may include other variables. A variable is anything which can assume more than one value. A model can stipulate the magnitudes which variables may assume under specific conditions. A variable may be independent so that, when varied, it appears to induce change in another variable. A dependent variable is a variable whose values change in response to changes in the independent variable. An intervening variable helps to explain linkages between variables, and a moderator variable is one which induces change in the relationship between other variables.

3.3.1 Sidwell's (1982) research

Sidwell (1982) identified that the building team is the centre of the building process which supplies all the design, managerial and constructional skills necessary to realise a building project. He conducted a research which aimed at examining the function of the building team, and the various forms in which it may be organised, and to assess the merits of these forms. The aim of this model was to show the relationship between the variables present in the building process and their influence on the performance of the building team as well as the outcome of the building project. Also, it might be used to assist in the selection of those organisational forms and project procedures that are appropriate to individual client and project characteristics and that will therefore result in project success.

The variables were classified into six headings. The elements 'client characteristics' and 'project characteristics' were seen as primarily independent variables. To operate the model, one would start with an assessment of the characteristics of these two variables. In response to this, the next two moderator variables, 'project procedures' and 'building team', were selected or adapted in order to serve the needs of the two primary independent variables: the objective being to achieve optimum results of the fifth, dependent variable of 'project success'. The variables 'client' and 'project characteristics', 'project procedures', and 'building team', comprised the organisational form. These variables, including 'success', were all subject to the influence of the sixth element of the model, the 'environment'.

Several statistical methods, such as chi square test, Pearson's correlation coefficient, McQuitty analysis and Scattergrams, were used in this research.

3.3.2 Ireland's (1985) research

Ireland (1985) developed a building process model which aimed at investigating the relationships between the use of particular managerial actions or approaches and their effects on the achievement of goals and objectives. The research objectives included 'reduce the cost of building', 'reduce the time of construction' and 'increase the architectural quality'. The variables in the research model were grouped under four headings, which include 'technological effects', 'structural effects', 'psychological effects' and 'managerial effects'. The methods used to test propositions were partial correlation and multiple regression.

Partial correlation was used to show that association occurs between variables and to indicate the probability of the associations; multiple regression was used to show the relative strengths of the effects of the variables. Partial correlation is a particularly useful, rigorous method of analysis for showing that two variables are associated; that is as one variable increases, the other variable also increases; or, as one variable increases, the other variable decreases. The multiple regression analysis shows the strength of relationships between variables, especially the relative effects of the particular managerial actions on the achievement of objectives.

There is some new analysis methods, such as artificial neural network which is more advantageous than regression model. Besides, it can do the analysis with a limited amount of data.

Artificial neural networking (ANN) is a relative new method of modelling. This method can perform the similar function as statistical method but it has competitive advantages as it can predict the result based on limited data. The advantages of ANNs include that one can 'learn data and experience in order to predict outcomes' and the model 'automatically adjust the weights of the input in order to optimise the behaviour'. Besides, the system can still perform well even if it contains some irrelevant data (Boussabaine, 1996).

Regression analysis was the traditional method used for analysing the data. The advantage of this method was to show how the identified variables influenced the outcomes. However, in practice, it needed a lot of data such as artificial neural network, in order to run a successful model.

The purpose of these two models was to identify the critical factors which influences project performance. There were a number of similar research projects such as Ashley et. al. (1987), Atkin and Flanagon (1995), Morris and Hough (1987) and Rowlinson (1988). They went through a comprehensive process in order to identify an extensive list of factors, Ashley et. al. (1987) identified 46 success factors for construction project.

3.4 Data management model

A data management model is a system which identifies the data flow between different information activities and it is usually shown in a data flow diagram.

3.4.1 Integrated Building Process Model (IBPM)

Sanvido and Norton (1994) developed the Integrated Building Process Model (IBPM) and used the Integration Definition language 0 for Function Modelling (IDEF-0) as the modelling technique. It represents a process as a sequence of activities, described by a verb followed by a noun. Each activity has associated inputs, outputs, controls and mechanisms.

The IDEF-0 models are composed of blocks and arrows. The blocks represent functions: activities or processes to be performed. Arrows represent data or the means by which a function is accomplished. Inputs to a function are shown on the left side of the block and outputs are shown on the right side. Arrows entering the top of a block are controls that constrain or influence the function. Arrows entering the bottom of the block indicate mechanisms that perform the process or operation. The IDEF-0 technique essentially represents a process as a sequence of activities, described by a verb followed by a noun. Each activity has associated inputs, outputs, controls and mechanisms. IDEF-0 diagrams are structured hierarchically in such a way that general activities are presented on upper levels and more detailed descriptions of activities are presented in lower levels.

The Integrated Building Process Model (IBPM) was designed to provide open information on architecture in order to support the provision of a facility. It aimed at providing a computer-integrated model which defined critical success factors for construction projects.

It consisted of four hierarchical levels, which included 'essential functions', 'required to manage', 'design plans' and 'construct and operate a building'. Further at each level, it contained sub-functions of each level, such as contract, design plan, construction plan, operation plan and facility plan etc.

One of the deficiencies in this model was that it was unable to differentiate between value adding and non-value adding activities. It also did not differentiate resources and constraints in inputs. Moreover, it did not incorporate any future learning capability into the model (Kartam et. al., 1997).

To a certain extent, Sanvido and Norton (1994)'s model has applied the 'system thinking' concept to construction project. However, it has ignored two major elements, i.e. environment and feedback. A system does not stay in an 'isolated' situation. The external environment will influence it and this can make projects difficult to manage (Bennett, 1985). Feedback is another important concept. The aim of feedback is to regulate and improve the performance of the project (ibid.).

3.4.2 Karhu et. al.'s (1997) Research

Karhu et al. (1997) prepared another example of research on data management. This study modelled the overall construction process systematically creating a generic present-state model covering the design and construction of a building project from the conception of the project in a client's mind to its completion for handover and use. This model has six sub-models: client's work process model, architectural design process model, structural design process model, building services design process model, geotechnical design process model and production process model. The resulting process model covers the activities done by the client, various design professionals and the general contractor. The main focus of this model was on the functions and flows of the process since it was found that such aspects might be most critical in the development of the building procedure. Like Sanvido and Norton (1994)'s research, this model also adopted IDEF-0 as a modelling technique.

There were several common disadvantages among Sanvido and Norton (1994)'s model and Karhu et. al.'s (1997) model. Both models were static models as they intended to model the construction process but they were not able to be updated after inputting information. Besides, there was a lack of interface in these two models and they were unable to provide advice or a recommendation to the user.

3.4.3 Information/ Integration of CONstruction (ICON)

Information/ Integration of CONstruction (ICON) is another research model which focused on data management (Aouad et. al., 1994). The main objective of this project was 'to investigate the feasibility of establishing a framework for integrating information systems encompassing the functions of design, procurement and construction'. This framework would then form the base from which the construction industry could develop a long-term information systems development strategy and a generic information model.

ICON has used a hybrid approach of Information Engineering (IE) and Object Orientation (OO) in order to develop more effective information models for the construction industry. Information Engineering was used to derive a contextual model for the integrated database in terms of activity decomposition. This was then transferred to an object-oriented computer-aided software/ system engineering (CASE) tool for further analysis and decomposition. Once a framework for the integrated database had been established, the next phase was to carry out conceptual modelling of the areas of design, procurement and management of construction using object oriented techniques.

As the aim of this model was to develop a framework for an integrated information system, this project is more likely to reflect a construction information database rather than a model of the construction process. A database is a static model which stores information, but it will not provide advice for the users. Besides, it provides no mechanisms for sharing information between industries. Even disregarding other industries, modelling and integrating construction information is also difficult to achieve. Moreover, this model considered 'activities' only, it did not consider 'roles' which must be considered within a successful model.

The methodology for developing ICON is also subject to criticism. Information Engineering (IE) is one of the methodologies used in this project. In principle, this method is suitable for activities which may not reflect widely held industrial distinctions between domains. However, construction is arguably not such a situation. In other words, ICON has not used the appropriate methodology (Rezgui et. al., 1996). Besides, the data source of the model is also subject to criticism. The source of data of this model is from architect, quantity surveyor and contractor only, but it did not consider the opinion from other construction parties (Sheath et. al., 1996).

The data management models did not facilitate the essential improvement required by the UK construction process. A study undertaken by the Engineering Design Centre at the University of Newcastle upon Tyne, found that within the problems related to the performance of the process only 16% were data management related (Sheath et. al., 1996). Besides, IDEF-0, the most popular modelling technique of data model was also subject to criticism as feedback was difficult to model and it was difficult to reuse the model parts in a modular fashion (Karhu and Lahdenpera, 1999).

3.5 Non-data management model

Non-data management models focus on the modelling of activities in the project and their casual relationships using graphical diagrams.

3.5.1 Royal Institute of British Architects (RIBA) Plan of Work

The RIBA Plan of Work (RIBA, 1995) was one of the first expressions of the building process developed by members of the building team (first edition published in 1969) and it is one of the most utilised non-data focused construction process models.

The RIBA Plan of Work is essentially an activity model of the traditional building process classifying the construction process into twelve stages. It was developed from the viewpoint of the architect and identified the construction activities in the whole construction cycle. Additionally, it also provides specimen business letters for use throughout the project cycle.

However, in practice this model may be biased towards the status and role of the architect as it was prepared by the RIBA. Although it mentioned the role of other participants, its description is very shallow and brief. Furthermore, the activities are 'identified' only. It does not mention their sequence and who are the responsible parties.

The changes within the construction industry have been substantial in the last five years. Although the RIBA Plan of Work published the updated version in 1995, it still does not embrace all the post Latham issues and it does not reflect the new construction environment. In the late 1990's, many new construction management issues, included, total quality management, risk management, value management, safety management etc. Although the nature and the focus of these issues are different, their purposes are similar that is to improve the efficiency of the construction industry. Unfortunately, the RIBA Plan of Work has not been considered and incorporated these issues.

3.5.2 British Airport Authority's (BAA) Process Model

BAA's Process Model (BAA, 1995) is another non-data focused construction process model. The BAA model goes beyond the simple sub-division of phases and breaks the process down into the key sub-processes like development management, evaluation and approval, design management, cost management, procurement management, health and safety, implementation and control, commission and handover. Each sub-process is conducted in some form, throughout the process, and this grouping of activities may be seen as ensuring the effective execution of the process. In addition, the model incorporates a 'stage-gate' review and approval routine between each phase in order to control the process.

The BAA model shows an improvement compared to the RIBA Plan of Work. However, its main application is at a generic level. The BAA model was developed from BAA's perspective and it focuses on its company condition. Therefore, the model takes little account of the need for improvement of the general construction environment and industry. Besides, the BAA model has designed its own identification of the construction stage. It therefore imposes limitations on those using it as a reference model.

3.5.3 National Health Service's (NHS) Capital Investment Manual

Some government departments, like the National Health Service (NHS) have also published a report which focuses on discussing the issues regarding the roles and responsibilities of construction participants in a construction process (NHS Executive, 1994).

This report noted the related issues regarding the appointment of architects, surveyors and engineers for commissions in the National Health Service (NHS). Apart from listing the roles and responsibilities of construction participants throughout the different stages, it also stated the information relating to the conditions of appointment, provision for fees and expenses and specimen certificates etc. The information provided in this document is similar to the RIBA Plan of Work, but it focused on NHS projects.

The NHS model faces similar limitations as the BAA model. The model lacks general application as it focuses on NHS projects and it has developed its own phase classification. Besides, the approach of this model is to identify the related documents and mention the related procedures. It operates in the reverse way to the other process models. The disadvantage of this approach is that it cannot reflect the construction activities in a 'sequential' order.

3.6 Models which consider roles of participants

These models are more advanced than the previous models as they have addressed two drivers for change that have been mentioned in the Egan Report, i.e. integrated processes and commitment to people. These two issues are also the fundamental reasons for causing under-achievement of the construction process.

3.6.1 Process Protocol Level 1

Kagioglou et. al. (1998) have done a research project named Process Protocol Level 1. They developed a generic design and construction process protocol. They adopted the New Product Development (NPD) process as the development approach.

The aim of this project was to develop a consistent process model which emphasised the principle of 'front-end' activities. This means that attention should be paid at identification, definition and evaluation of the client requirements before the project is started. This project had six main principles which included: whole project view, consistent process, progressive design fixity, co-ordination, stakeholder involvement and teamwork and feedback. Besides, it has four main phases, which are Pre-Project, Pre-Construction, Construction and Post-Construction, and it is further divided into ten phases, which are from Phase 0 to Phase 9. The horizontal X-axis illustrates time in process and the individual process activities or gates. The vertical Y-axis is the activity zone. The activity zone is the spectrum of task, which identifies the parties responsible for construction activities. The activity zones include development management, project management, resource management, design management, production management, facilities management, health and safety and process management. Additionally, there is a phase review system and a report can be provided for each phase. Apart from describing the activity in a map, it is necessary to use multiple computing skills which include electronic data interchange, artificial intelligence, integrated databases, inter/intranet applications and document management systems, in order to analyse the activities and present the results.

This research developed a new construction process model at a macro level and produced a process model which could be applied to any construction procurement route. It had the advantage of general application but at the same time may face the weakness of 'lack of focus'. Within the model, the authors developed a new classification on construction phases and using activity zones to represent the roles of the responsible parties. This approach is new to construction practitioners and this model requires a high knowledge of computing skills in order to develop and model the construction activities. It is a good trend as it makes the model more sophisticated; however, in practice, it may be too complicated for the non-computer literate user.

3.6.2 Austin et. al.'s (1999) research

Austin et. al. (1999) stated 'having a team pre-defined the process for themselves helps the members adhere to a program and work in accordance with it. Lack of a pre-defined process appears to result in unfruitful and opportunistic behaviour by the team or some of its members' (p.11). Therefore, they developed a process model, which highlighted the need for greater 'front-end' activity in the process and put the greater emphasis on the feasibility and design of the construction process.

The model that they developed has shown that effective interdisciplinary design activity relies on all of the team members supporting each other and the interaction of each member within the project team. The model consists of 12-phases and they are grouped into five stages (Steele et. al., 1999). These 12 phases include: specify the business need, assess functional requirements, identify essential problems, develop functional requirements, set key requirement, determine project characteristics, search for solution principles, transform and combine solution principles, select suitable combinations, firm up into concept variants, evaluation and choice of alternatives as well as improve details and cost options. The first three phases are 'for gaining an understanding of the nature of the best'. The second three phases are 'develop the design parameters', the seventh phase are 'diverge', the eight to tenth phases are 'transform' while the last two phases are 'converge'.

This model can also be applied to any procurement route and introduces the classification of construction stages in the project. However, the weakness of Austin et. al.'s research is similar to the Process Protocol research; it may be too complex for the non-computer expert.

3.7 Generic building process model

Lahdenpera (1995) developed a generic structure of the overall building process organisation. The aim of this study was to define the most appropriate generic structure of the overall building process organisation for the Western countries in the future. He introduced a building process model with an emphasis on ten principles, which included: (1) consumer-oriented phased and focussed decision making, (2) distinction between the shell and interior of the building, (3) performance approach in planning and specification, (4) competition based on implementer's technical solutions, (5) extended commercial means of competition, (6) activation of research and development, (7) establishment of system units for assigning scope of liability, (8) industrial component production, (9) system-unit based multi-skilled teams on site and (10) continuous collaboration between parties. The author reviews the existing building system in several countries, including Finland, France, Japan and Holland, in order to find out the implication of the construction industry in these countries and make recommendations to the ten principles.

The reason for identifying these four countries is that they have different productivity; poor productivity being one of the main problems within the UK construction industry.

The Finish system of procurement is an approach which focuses most exclusively on the analysis of the production organisation. The fundamental idea is to improve overall productivity and quality primarily by clarifying liabilities and improving motivation which also improves the preconditions for development work. The French sequential procedure is based on organisation of work in the implementation phase, though it has expanded into versatile development of production. The fundamental idea is to improve productivity and cut waste in the process while minimising risks in general and creating the preconditions for effective utilisation of technology. The Japanese computer-integrated construction process is highly technology-centred. The fundamental idea is to improve information flow and process control using new technology and to speed up implementation. Other very important goals are better working conditions and minimal dependence on labour. The Dutch open building system is mainly concerned with the customer's needs and changes in them, even during the erection. The fundamental idea is to efficiently produce buildings and spaces of prefabricated components that meet the customers' individual needs. The space must also be modifiable which again emphasis life-cycle economics.

Lahdenpera discussed the characteristics of the construction industries in these countries and identified the implications on the ten principles. Afterwards, he presented the relationship of the philosophies with the devised recommended principles.

The method used to develop the model was by the so-called problem-solution analysis. This method did not describe the construction process, but rather conducted the argument chains for analysing problems and solutions in construction (Lahdenpera, 1995).

The advantage of this model is that it addresses one of the aims of the Egan report, i.e. 'focus on the construction process'. However, this research did not develop a construction process model. It aimed at providing recommendations for the construction industry after reviewing the building process system in different countries.

3.8 Reflection and conclusion

After reviewing the previous research on construction process modelling, it was found that there are insufficiencies in all the different models and approaches.

These insufficiencies are identified as follows:

- Practitioners do not generally welcome the use of the models as they are too theoretical, e.g. regression models
- Not widely applicable as the models focus on company perspective or particular sector, e.g. BAA and NHS models
- Not updated and some are bias to a certain sector, e.g. RIBA Plan of Work
- Ignore some important construction concepts, e.g. IBPM and Karhu's (1997) research
- Not a process model, e.g. ICON and generic building process model

- Lack of focus and using too much IT skills, e.g. Process Protocol Level I and Austin et. al. (1999)'s model

A new approach for modelling the construction process has therefore been developed using a knowledge-based expert system. The development of this system will be discussed in the later chapters.

Chapter 4

Review of process modelling methods

4.1 Introduction

Increased globalised competition and the need to meet continuously changing customer requirements have forced the manufacturing industry to consider the key activities from a 'process' viewpoint. The advantage of this viewpoint is that it can organise and manage the operations more effectively.

The construction industry, particularly in the UK, lags behind that of manufacturing in terms of both productivity and efficiency, as there is no agreed procedural mechanism for doing the work. The reason for this situation is because of the fragmented nature of the industry and operation of its activities, and the perceived uniqueness of construction projects. Recent reports by the government (e.g. Latham report and Egan report) and the research council (e.g. Aouad et. al., 1998; Finnermore et. al., 2000) have addressed these issues and clearly stated that the way forward was to think of construction as a manufacturing process.

Egan (1998) argued that although the product of construction is unique, the process of producing the product, i.e. the construction process, is itself repeated. It mentioned that research suggests that up to 80% of inputs into buildings can be repeated. Therefore, the Task Force of this report believes that construction can learn from other sectors of the economy in tackling the problems in the construction process.

Adopting the developed modelling methods in other industries to the construction process is common; the aim of this chapter is to discuss the methods which have been widely used in the previous researches.

4.2 Manufacturing process concept

The early process models focused on modelling the construction process only, i.e. post contract. Walker (1985) adopted the manufacturing process concept and developed the conversion process model. According to this model, production is understood as the process of converting materials and labour inputs to product outputs. Furthermore, production processes can hierarchically be divided into sub-processes. Moreover, the cost of the total process can be minimised by minimising the cost of each sub-process and the value of the output of a process which is associated with costs (or value) of input to that process.

However, applying this conversion model to the construction process in order to analyse and manage productive operations can be misleading. One of the essential problems in the conversion model is that it does not differentiate between value adding activities and non-value adding activities. Non-value adding activities are those activities that add no value to the process, but add cost; waiting for materials, waiting for instructions, rework, and inspection are considered non-value-adding activities in the construction process.

The proportion of the non-value adding activities is very high in the construction industry, e.g. 30% of construction is rework (Egan ,1998), ignorance of this aspect will tremendously reduce the usability of the model.

It also neglects the important aspect of resource flows. For instance, one of the key premises is that the total cost of a process can be minimised by minimising the cost of each sub-process independently. In addition, it neglects output variation and rework. It assumes that work passes linearly and sequentially through a system. Moreover, the conversion model neglects the impact of poor quality inputs as well as the impact of variability and uncertainty.

Unfortunately, in the more complex production process, flow activities rather than conversions cause a major part of the total costs (Kartam and Ibbs, 1996; Koskela, 1992).

4.3 New production philosophy

Conversion (production) is the flow of material and/ or information from raw material to the end product. In this flow, the material is processed (converted), inspected, waiting or being moved. Processing represents the conversion aspect of production; inspecting, moving and waiting represent the flow aspect of production (Koskela, 1992).

Flow processes can be characterised by time, cost and value. Value refers to the fulfilment of customer requirements. In most cases, only processing activities are value-adding activities. For material flows, processing activities are alterations of shape, substances, assembly and disassembly (ibid.).

This approach is more advanced than the traditional approach, as it considers not only the conversion process but it differentiates between conversion activities and flows activities.

Koskela (1992) used this method to develop a new conceptual model for the direct production process. The key term in this project was 'Just In Time' (JIT) and 'Total Quality Control' (TQC). This new production philosophy conceives production activities as materials and information flow processes. These processes are tightly controlled for minimal variability and cycle time, and improved continuously with respect to waste and value and regularly in regards to efficiency by implementing new technology.

This model has an advantage over the previous model because it differentiates between value adding and non-value adding activities. It also concentrates on process flow rather than on exchange along the process because the rule of this model is that only processing activities are value adding in this model.

However, this model also has some disadvantages. It is only a process model, it does not realise the system concept and ignores process interactions and interdependencies. It does model the production process but does not very well model the management process that affects production process, especial those that are administrative driven (Kartam et. al., 1997).

4.4 Simulation

Simulation has been a popular modeling method in the 1990's. Computer simulation is defined as the process of designing a mathematical-logical model of a real-world system and experimenting with the model on a computer (Hajjar and AbouRizk, 2000).

Within the last 20 years, considerable progress has been made in developing sophisticated simulation-based methods in order to analyse the construction process. Related research includes AbouRizk and Halpin (1990), McCahill and Bernold (1993), Oloufa (1993), Sawhney and AbouRisk (1995) and Vangeas et. al. (1993) etc.

Shi (1999) has done the most recent research on this topic. His research presents the activity-based construction (ABC) modelling and simulation method. ABC modelling (ABC-Mod) uses one single element (e.g. activity) for modelling the general construction process instead of multiple elements as required by current simulation systems. ABC can be considered as a general-purpose model and a simulation method with an emphasis on construction application. Compared with current simulation systems, it has all of the major features required for modelling and simulating the dynamic and random behaviours of a construction process.

Computer simulation has great attraction in its generality. Building a simulation model does not require any extensive mathematical background and can in principle cope with any degree of complexity and interdependence between model components (Kreutzer, 1986).

However, the development process of a construction simulation tool is a time-consuming and complex operation. Besides, it requires high cost for setting up the equipment, which in practice becomes a major obstacle for companies. The other major problem for using simulation stems from the lack of a consistent approach that clearly defines all the steps and aspects of simulation (AbouRizk and Halpin, 1990; Hajjar and AbouRizk, 2000; Shi and AbouRizk, 1997).

It is also difficult to ensure the development of a 'bug-free' simulation model. The primary level of difficulty is 'collection of data'. Banks and Carson (1984) stated 'even if the model structure is valid, if the input data are incorrectly collected, inappropriately analyzed, or not representative of the environment, the simulation output data will be misleading and possibly damaging'. The second level of difficulty is related to the validation of the model. Morgan (1984) and Neelamkavil (1987) mentioned that a detailed checking of the simulation output of a model against observed data from the real-life system that is being modelled, can provide challenging time-series problems.

4.5 Capability Maturity Model (CMM)

Standardised Process Improvement for Construction Enterprises (SPICE) is the second stage development of Process Protocol. It builds upon the basic concept of process maturity, which was introduced through the Capability Maturity Model (CMM).

The CMM framework organises these steps into levels that lay successive foundations for continuous improvement. Each level comprises a set of process goals that, when satisfied, stabilise an important component in the process. Achieving each level of the maturity framework establishes a different component in the process, resulting in an increase in the process capability of the organisation. The principle of this model is that 'little value is added to the organization by addressing issues at a higher level if all the key processes at the current level have not been satisfied'. Therefore, with the implementation of this concept, effective and continuous improvement can be achieved based on evolutionary steps.

It attempts to develop an evolutionary step-wise process improvement framework for the construction industry. The SPICE framework will enable construction organisations to improve their processes over various levels of maturity (Sarshar et. al., 1998).

There are six evolutionary levels which are identified in SPICE. These include: chaotic, planned and tracked, well-defined, supply chain alignment, qualitative control and continuous improvement. The emphasis in different levels is various and it follows the development of the progress in construction process.

The SPICE framework is not prescriptive. It does not tell an organisation how to improve. SPICE describes the major process characteristics of an organisation at each maturity level, without providing any guidelines on how to improve the process. Instead, it provides a set of common process capability features, which all processes need in order to achieve capabilities. These common management features are (i) commitment to perform, (ii) ability to perform, (iii) activities performed (iv) analysis and evaluation and (v) verifying implementation (Sarshar et. al., 1998).

SPICE ignores the importance of 'time' in the construction process as this model is based on a 'one-way sequence' of construction activity. It is quite usual to overlap activities or execute them in parallel. This argument is also justified by the result of a recently organised workshop (Austin et. al., 1999). They stated 'although a linear sequence of phases was pre-defined by team (A) it is apparent that the design actually progressed linearly but in a number of iterative bursts' (p. 6). It concluded that the principle of 'promote to the next successive foundation only if the lower level has beeh satisfied' may not always be realistic (ibid.).

4.6 Reflection and conclusion

Facing the same situation as the previous construction process model described in chapter three, the models which are use different modelling techniques have some insufficiencies in different aspects.

The set up and operation cost of the simulation model is high, therefore the practitioners do not generally welcome the use of the models.

Finally, the models which adopt manufacturing process concept, new production philosophy, and CMM as the modelling techniques ignore some important construction concepts, so it hinders the usefulness of these models.

The new process model which is necessary to be developed and the development process will be discussed in the later chapters.

Chapter 5

Theoretical framework of CONstruction Best Practice System (CONBPS)

5.1 Introduction

Having discussed the previous construction process research in chapters three and four, it was found that they have different levels or kinds of insufficiency. It is necessary to develop a new construction process model. The CONstruction Best Practice System (CONBPS) is developed by an expert system. It can provide the 'questions and answers functions', and can make recommendations on additional information based on the answers of the users. Furthermore, it will provide the interim reports throughout the process and a final report at the end of each construction stage.

5.2 Development of a process model for successful building projects

5.2.1 Methodology for developing the framework

The standard cycle of work in a building project identified in the RIBA Architect's Job Book (1995) and known as 'the RIBA Plan of Work', has been chosen as a skeleton framework (see appendix one). The reasons for choosing it, as the framework is to increase the familiarity of this newly developed system to the potential users.

The RIBA Plan of Work is the most popular and common-used reference for building projects which are based on the traditional procurement strategy. Besides, it is the only model available and is well known by all construction practitioners and it has been widely used for several decades. It listed the construction activities which are the responsibility of the architect in sequence. Also, it briefly mentioned the duties and responsibilities of other construction professionals. Besides, it also provides the checklist for each construction stage. However, the information on the RIBA Plan of Work made up only one third to one half of the activities in this new process model. The changes within the construction industry has been greater in the last five years than the past fifty years, therefore, new construction management issues should also be included. Besides, the RIBA Plan of Work is published by the architects' association, it is more focused on the job nature of the architect, and ignores the duties and responsibilities of other participants. Therefore, the framework has included extensive information from other documents.

The other activities are abstracted from the information in various documents and they are listed below:

- The RIBA Plan of Work identified within the Architect's Job Book (RIBA, 1995)
- Responsibilities of the quantity surveyor identified by the RICS (RICS, 1983)
- Responsibilities of the contractor in the traditional procurement method (CIOB, 1996; NJCC, 1989)
- Procedure for single-stage tendering identified by the NJCC (NJCC, 1989)
- Responsibilities of the client identified by the Construction Clients Forum (CCF, 1998)
- Current government publications concerned with improving performance of the construction industry (CIB, 1996 and 1997; HM Treasury, 1993, 1994, 1996 and 1998)

- Official advice on health and safety within the construction industry (HSC, 1995a and 1995b; HSE, 1994)
- Design management concept for construction (Gray et. al., 1994)
- Environmental management concept for construction (Griffith, 1997)
- Constructability concept (CII, 1986)

The information is abstracted, transferred to activities and located in the appropriate location of this process model.

The updated model incorporates the following modern construction management issues:

Risk management

Numerous sources stated that the construction industry has been subjected to high risks (Akintoye and MacLeod, 1996; Shen, 1997; Skyes, 1982); mainly due to the unique characteristics of construction projects. Akintoye and MacLeod (1996) have stated 'the construction industry and its clients are widely associated with a high degree of risk due to the nature of construction business activities, processes, environment and organisation' (p.31). Shen (1997) further explained and confirmed this idea. He stated 'previous research suggests that construction activity is particularly subject to more risk than other business activities because of its complexity; a construction project usually requires a multitude of people with different skills and interests and the co-ordination of a wide range of disparate, yet interrelated, activities. The unique features of a project and many other external uncertainties further compound such complexity. It is not uncommon to find construction projects with cost overrun, time delay and poor quality caused by various risks' (p. 101). So it can be concluded that no construction project is risk free. Risk can be managed, minimised, shared, transferred or accepted, but it cannot be ignored (Latham, 1994).

Appropriate risk management method must be chosen, otherwise, risk management may 'adversely affect the project sponsors ability to achieve the project objectives' (HM Treasury, 1993: p.1). Risks are not stated in isolation, it is not specific to the physical nature of the project, but they are associated with the project process. Therefore, risk management should become an integral part of the project management process and implemented throughout the whole process (CIB, 1996; HM Treasury, 1993; Latham, 1994).

Value management

Value management is a systematic, strategic and multi-disciplinary effort which maximises the functional value of a project by managing its development from concept to completion and commissioning through the audit (examination) of all decisions against a value system determined by the client. It aims to achieve the best value at the lowest overall life cycle project cost (Kelly and Male, 1993; Norton and McElliogott, 1995).

In other words, the primary objective of value management is to provide the product to the client, which is value for money and it is the same as the basic expectation of the client (Chinyio et. al., 1998; HM Treasury, 1998). Besides, it is also concerned with the overall process of the construction project. This means that it does not only consider the outcome, but also the process. In a well-managed study, all parties can achieve significant benefit from both the process and the outcomes (Neasbey et. al., 1999).

Total quality management (TQM)

The world is in continuously progressing, 'the highest standards in the world are becoming the standard for all. Therefore, most organisations need to change their concepts of 'quality' and 'customer' in order to survive in the competitive world. Total quality management (TQM) is one of the techniques to meet these ends (Tam and Hui, 1996). 'All companies must institute TQM or become non-competitive in the national and international construction and engineering markets within five to ten years' (Burati et. al., 1992: p.113). The two fundamental goals of TQM are customer satisfaction and continuous improvement.

The goal of TQM is especially suitable for the construction industry as its fundamental goals is same as the insufficiency of the construction industry (Deffengaugh, 1993). Burati et. al. (1992) have stated 'the function of the construction industry is to provide customers with facilities that meet their needs. For a company to remain in business, this service must be provided at a competitive cost. TQM is a management philosophy that effectively determines the needs of the customer and provides the framework, environment, and culture for meeting those needs at the lowest possible cost' (p.113). Practically, TQM has demonstrated its function of improving construction performance. Neil Muller Construction of South Africa used Total Quality Management techniques to achieve an 18% increase in output per employee in one year, a 65% reduction in absenteeism in four years, and a 12% saving on construction time on a major project (Egan, 1998: p.15).

Safety management

Safety is a rising issue in recent years. This is because the construction industry is one of the most dangerous industries in the nation and the combined injury and illness rate in this industry is higher than for all other industries except for agriculture (Jaselkis et. al., 1996). This can be reflected in the data issued by the National Safety Council (NSC). According to the survey prepared by are NSC, construction accidents claimed 1,300 lives in 1993. Workers' compensation rates have increased dramatically in nearly two decades. From 1974 to 1994, for example, general carpentry rates increased an average of 3.8 times in the United States; structural steel erection manual rates increased nearly 3.5 times for the same time period (Jaselkis et. al., 1996).

The government has also become more concerned on health and safety on construction projects. Government legislation, Construction (Design Management) CDM Regulations was been passed in 1994 in order to improve the safety record of the industry.

Design management

The primary aim of a construction project is to produce a high quality building. Design is a complex process, which continues to grow in complexity because of the dramatic increase in specialist knowledge. There are now many contributors to the design of a project from a wide variety of organisations. This gives rise to design processes which consist of continual exchange and refinement of information and knowledge. In other words, building design has now become an integral part of a complex industrial process and there is a need to identify the management task and manage it well.

Environmental management

The construction industry is one of the industries which causes tremendous effects on the environment. The best method in order to minimise the effect is to implement control systems in the construction process.

Partnering

Many reviews have criticised the under-performance of the UK construction industry. The potential is at present inhibited by adversarial attitudes, which waste the time for improvement of talented people in unproductive disputes.

Partnering has emerged as the method for improving construction performance. Researchers from the University of Reading defined partnering as 'a set of strategic actions that deliver vast improvements in construction performance' (Bennett and Sayes, 1995). Partnering provides the logical next steps in the development of modern industry management practice leading to a decrease in project disputes (Bennett and Sayes, 1995; Stephenson, 1996). Besides, partnering provides a good basis for value engineering and simplifying procedures, contracts and specifications. This potential should be used to build continuous improvement into the heart of the partnering arrangement (Bennett and Sayes, 1995).

Benchmarking

Benchmarking is a process of continuous improvement and the search for industry best practice that leads to superior performance. It should be incorporated as it is the procedure for finding the best practice in the industry.

Constructability

Constructability is optimising the use of construction knowledge and experience in planning, design, procurement and field operations in order to achieve the overall project objectives. Maximum benefits occur when people with construction knowledge and experience become involved at the very beginning of a project (CII, 1986).

5.2.2 Reasons for choosing the criteria

The key criteria within this model include time, cost, quality and safety. The first three criteria are the traditional determinants of project success. Safety is an additional factor which should be included.

The construction industry is one of the most dangerous industries in the nation and construction accidents can cause both loss of human life and loss of money to the parties (Sawacha et. al., 1999).

Apart from these criteria, certain 'hotspots' are also identified within each stage of the project cycle. The 'hotspots' are the 'critical activities', to which each participant should pay special attention in order to ensure satisfactory performance before proceeding to the next stage. The idea of 'hotspot' has been widely used in government and academic literature. Kagioglou et. al. (1998) introduced the concept of 'phase review' into the Process Protocol Level 1 Report. 'The phase review consists of two elements, which are 'soft' and 'hard' gates. 'Soft' gates enable concurrency in the process whereas 'hard' gates require the temporary overhaul of the project until a decision to proceed is made... The intent of each gate is to assure a high quality of work performance by multifunctional teams at each phase of the project' (p.1:15). Her Majesty's (HM) Treasury (1998) published the 'Procurement Guidance No.2: Value for Money in Construction Procurement' which also developed the same concept. It identifies the 'approval gateway' at the critical points in the project cycle. The users should take appropriate action at such gateways. The concept of 'hotspots' in this project follows this direction.

5.2.3 Parties responsible for construction activities

The participants, at the pre-contract stage, include the architect, quantity surveyor, client and the planning supervisor. The architect, quantity surveyor and client are identified as they are the identified participants in the Standard Condition of JCT Contract. The planning supervisor is also an important party in the building process. In the traditional procurement strategy, contractors will not participate in the project until the estimating stage.

The planning supervisor is a relatively new role in the construction process that was introduced following the implementation of the Construction (Design Management) CDM Regulation in 1994. They have overall responsibility for co-ordinating the health and safety aspects of the design and planning phase for the early stages of the health and safety plan and the health and safety file (HSE, 1994).

5.3 Framework of new process model for building projects

The framework of the process model has been developed on the twelve construction stages, which is from inception to feedback. Besides, all of them have been sent to practitioners for comment at the pilot survey. Only conceptual design stages, that is from inception to scheme design stage, have been developed in the prototype expert system.

5.3.1 Framework for scheme design stage

The pre-contract Stage D "Scheme Design" has been chosen for demonstration purposes (see figure 5.1). The frameworks of the rest of the construction stages are shown in appendix two. This information has been updated after receiving the comments from practitioners (see sections 8.2 and 8.3). The reason for choosing this stage is because it is one of the most critical stages in the project cycle as it is the transition stage from 'briefing' to the production of 'working drawings'. As it is within the pre-contract stage, there is no role for the contractor in this stage under the traditional procurement route.

Figure 5.1 Framework for scheme design stage

5.3.2 Description of first column

The diagram is divided into three columns. The first column states the *criteria.*

Time, cost and quality are the well-known traditional determinants of project success. Safety is an important issue and should also be included in the model.

The 'hotspot' identifies the 'critical activities' within each stage of the project cycle to which each participant should pay special attention in order to ensure satisfactory performance before proceeding to the next stage. The method used to identify the 'hotspot' activities is based on three steps. The first step is identification by the author after finishing the literature review, the second step is incorporating comments made by the supervisory team and the final step is incorporating comments made by the practitioners who participated in the pilot study.

As the practitioners in the pilot study are the representatives from a discrete construction sector 'Housing Association', their comments may not be fully complete as their understanding of construction industry may be limited. In order to ensure the accuracy and the appropriateness of the 'hotspot', the practitioners who were involved in the major survey and evaluation stages were be asked to comment their understanding of the concept of 'hotspot'.

5.3.3 Description of second column

The second column identifies the *participants* in the construction process. The participants include the architect, quantity surveyor, client, planning supervisor, contractor and sub-contractor.

The arrows show the sequence of work. If the activities reach the 'hotspot' and there is no agreement at that point, the participants should go back to certain activities and re-start the procedure again. In certain activities, only one party needs to participate; sometimes, contribution from several parties is needed.

Architect

Traditionally, the architect has to perform two roles, firstly that of designing a building and secondly that of administering the project. He does this by co-ordinating the contribution of consultants and then administering the building contract. Besides, he is also the first point of contact with the client and he is the person who interprets the client's brief into the building.

There has been a dramatic change in the architects' role in recent years and there is now no dual role for the architect. The architect acts as design manager who is responsible for co-ordinating design tasks (Gray et. al. 1994; RIBA, 1992). The loss of the leadership role means that the architect is no longer in a position to influence the rest of the construction process (RIBA, 1992). This is mainly because of the increasing competitiveness and the influence of the other professions. According to a study prepared by Smith and Morris (1992), out of a total of forty-four services listed in the Standard Form of Agreement (SFA/92) for the Appointment of an Architect, thirty-nine were undertaken by competing professions.

Furthermore, the architect's role as the strategic advisor for the client in the pre-design stage is also diminishing. The reason for this is because architects have failed to satisfy the clients. According to the RIBA (1992), 'their dissatisfaction would appear to have arisen as architects moved away from being responsible for programme and financial control, the areas of most concern to clients, toward pure design. It would also appear to have arisen because clients and architects have different perceptions of quality in construction. Architects tend to interpret quality in terms of the finished product while clients increasingly see it in terms of control of the design and the construction process' (p.70). Therefore, increasingly clients are looking to an independent professional to act in the role of the client's project manager.

Quantity Surveyor

The traditional role of quantity surveyor is of professional who provides advice about cost and financial management for the construction process. The traditional services provided are considered to be of a technical basis, such as preparing the cost plan and the bills of quantities, tender documentation and tender appraisal, interim payments, measuring and valuing variations, advising on anticipated final costs and preparing the final account (Burnside and Westcott, 1999).

The changing role of the quantity surveyor in recent years has been significant (Ashworth, 1981; Donohoe, 2000). Thirty years ago the perception of quantity surveyors was preparing bills of quantities and final accounts only. In recent decades, the emphasis has changed, with a shift from *cost* to *value* and the recognition of the importance of procurement and management skills (Ashworth, 1994). This argument is further supported by Keel et. al. (1994). According to the results of their survey, over eighty percent of clients interviewed see the role of the quantity surveyor changing. Sixty seven percent of respondents see an increasing role in the areas of project management, lead consultancy, cost and value management, mechanical and electrical services and advising on overseas methods and costs. Therefore, the term 'quantity surveying' does not now reflect the services that are provided, the term 'project cost management' is the more suitable term to describe the services provided.

The quantity surveyor is also important in the design process of construction. The earlier the participation of the quantity surveyor, the greater the advantage that can be gained. The quantity surveyor can give cost and financial advice to the architect in order to obtain added value within the design solution. In turn, this enables the client and the design teams to generate an economic and feasible design solution, which may be analysed to ensure that the client's requirements, are satisfied.

Client

Traditionally, the client is defined as the sponsor of the construction product or service (Ahmed and Kangari, 1995; Potter, 1995). There has been numerous research recommendations in recent years advising that clients should participate in the construction process (e.g. CIB, 1996; Latham, 1994; NEDO, 1975) and stating that their involvement is critical to the success of the project (Davenport and Smith, 1995; Kometa et. al., 1996; Thompson, 1991 etc.). Latham (1994) stated that 'implementation begins with clients' (p.3). The client's involvement during project development and implementation is critical to project success (Thompson, 1991).

Generally, the higher the level of client involvement, the higher the level of satisfaction. Gunning and Courtney's (1994) did an investigation on the private sector client contribution to the construction process in Northern Ireland. They drew the conclusion that 'if private sector clients take fuller control of their projects either directly or indirectly, they will be assured of improved satisfaction at the completion stage with their priorities constantly concentrating the minds of all other associates' (p.18).

Further research indicated that clients should be involved and provide a clear project objective (Bennett, 1985; Rowling et. al., 1987; Walker, 1995), and convey it into a precise and concise client brief (Bowen et. al., 1999; CIB, 1996 and 1997; Graham, 1983; O'Reilly, 1992; Smith et. al., 1998), considering that the client should also manage the project and project team (Bubshait, 1994; Potter, 1995) as well as performing safety management (D'Arcy, 1999; Smallwood, 1988).

Planning supervisor

The planning supervisor is a relatively new role in the construction process that was introduced following the implementation of the Construction (Design Management) CDM Regulation in 1994. They have the overall responsibility for co-ordinating the health and safety aspects of the design and planning phase and for the early stages of the health and safety plan and the health and safety file (HSE, 1994).

Contractor

Under the traditional contracting strategy, the level of participation of the contractor in the pre-contract stage is lower than in other procurement strategies. The contractor will not participate in the project until estimating the prices for the bills of quantities and they are obliged to build what the architect designs and instructs.

5.3.4 Description of third column

The third column shows the *activities* of the construction process, the numbers indicate the sequence of work. The information in this column is abstracted from various sources of literature that has been listed in the previous section.

The activities that are listed encompass the typical issues in the traditional procurement strategy, but also reflect the modern construction management issues.

5.4 Reflection and conclusion

This chapter has reported the development of the theoretical framework of CONBPS. This framework is divided into three columns, including success criteria, responsible parties and identification of construction activities.

The theoretical framework is the inputted information for the prototype of CONBPS and the development which will be discussed in chapter six.

Chapter 6

Development of CONBPS prototype

6.1 Introduction

Several methods, such as using quantitative analysis and developing a database, have been considered for presenting this model. Firstly, quantitative analysis has been rejected, as it cannot deal with the analysis and retrieve the expected qualitative result. Secondly, development of a database has also been rejected. Although it may compile the information and put it in a central database, it cannot provide advice to the users based on their answers. A database is simply a method for storing information, again, it cannot perform the functions that it is expected to do, e.g. give advice based on the responses of the users.

The most appropriate method to present this model is by using an expert system. The construction process is a sequential process; therefore, the activities produce a chain-effect. The expert system can provide the 'questions and answers function', and can make recommendations or additional information for each question. The user can follow the sequence and find the most appropriate way to approach each activity. The model should lead to greater efficiency and the final success of a construction project.

Having discussed the theoretical framework of CONBPS, the aim of this chapter is to discuss how to implement the theoretical framework into an expert system. This chapter is divided into six sections, the first two sections are the general discussion of CONBPS and its application on the construction industry, and the remaining sections discuss the development of the prototype of CONBPS.

6.2 Expert system – an overview

6.2.1 Definition and description

An expert system can be called a knowledge-based system. It is an interactive program, which contains expert knowledge. According to the definition given by the Special Group in Expert Systems of the British Computer Society (Watson et. al., 1994):

'An expert system is regarded as the embodiment within a computer of a knowledge-based component from an expert skill in such a form that the system can offer intelligent advice or take an intelligent decision about a processing function. A desirable characteristic, which many would consider fundamental is the capability of the system, on demand, to justify its own line of reasoning in a manner directly intelligible to the enquiry'.

An expert system attempts to model the intelligent reasoning and the problem-solving capability of the human brain. It is a computer program, which can provide expert advice for solving problems in a defined application. The user answers a question and will be led towards one or more recommendations. The questions are likely to be phrased in the jargon of the specialist field and the user will have the opportunity of asking the program how it arrived at its conclusion (Allwood 1989; Kasabov 1996; Moselhi et. al. 1991; Probst and Worlitzer 1988; Wager 1984).

Arditi and Patel (1989) have done a comprehensive review on expert systems and they found that the characteristics of expert systems are as follows:

- Expert systems are knowledge intensive
- Expert knowledge is usually dependent on rules that governs the logic of the subject for which the system is developed
- The rules forming a knowledge base are accompanied by an inference engine, a part of the software that processes data
- Expert systems are highly interactive and have a friendly/ intelligent user interface
- Expert systems mimic the decision-making and reasoning process of human experts to some extent
- Expert systems have incremental growth capabilities

6.2.2 Structure

A typical expert system contains four main components, which are: knowledge acquisition, inference engine, knowledge base and user interface.

Knowledge acquisition

The process of gathering domain knowledge from an expert (knowledge elicitation) and translating it into computer understandable format (knowledge representation) is known as knowledge acquisition. The knowledge acquisition of CONBPS will be further discussed in section 6.5.

Inference engine

The inference engine is where 'reasoning' takes place. It comprises the strategies for manipulating and executing the rules in the knowledge base. It 'decides' which questions to ask, evaluates the answers, and executes the appropriate rules to produce the solution. When the system searches for an appropriate rule, it may not arrive at a single conclusion, but at a number of possibilities having different degrees of certainty. Depending on the domain, the inference engine may use backward chaining or forward chaining.

The backward chaining is often described in terms of goal-directed reasoning. The inference engine chooses a likely goal and works backwards attempting to reproduce the process that lead to the approval of the goal. This goal-driven search method simulates deductive reasoning. In contrast, forward chaining starts with information in the database and the associated rules to generate a conclusion or goal. It is sometimes called data-driven reasoning because the inference starts from the known data and reasons.

Knowledge base

The knowledge base contains the facts and heuristics captured from a human expert. The knowledge base may include declarative or data-like knowledge as well as complex procedural knowledge, i.e. how to transform data. In some expert systems, the inference engine and knowledge are so intimately related that they cannot be separated into a distinct module.

User interface

The user interface facilitates all communication between the user and the system. The system asks for information through questions or multiple-choice menus, and the user answers by typing on the keyboard. As most expert systems are designed to be used by individuals with little computer literacy, user-friendly facilities, such as on-line help, explanation and error recovery, are essential parts of the user interface. The interface communicates with the user requesting information and providing advice on the subject as well as explaining the reasoning either for reaching a conclusion or for asking a specific question.

The user interface is important; without it, the expert system becomes a 'black box', incapable of seeking the additional information needed to conclude its work. Taken together, the user interface and the interface engine make up an expert system shell.

6.3 Expert systems in the construction industry

6.3.1 Suitability of expert systems in the construction industry

Several expert systems have been developed in the construction industry. The reasons of suitability are listed below:

- Even though construction projects are unique, there is a repetition of the process and procedures. According to the findings of the Egan report (Egan 1998), up to 80% of inputs into buildings are repeated. There is thus the opportunity to learn from earlier mistakes.
- Many construction activities are carried out at locations far from the home office, the source of the company's expertise; thus experts are often unavailable when and where they are needed. Maintaining full-time experts at each construction site

is not cost-effective and decisions must often be made quickly, without time to bring in outside consultants.

- Expert knowledge related to construction is, in the main, held personally by experienced practitioners and therefore is accessible only by piece-meal. An expert system is an attempt to counter this disadvantage by bringing together as many strands of expertise as possible, structured in a manner that helps a user to steer a step-by-step course in learning and so solve problems that are largely judgement dependent. To capture an expert's knowledge is time-consuming, laborious and complex, but where it is successfully achieved and superimposed onto a well-designed computer program, then it can facilitate the future process.
- Construction management consists of numerous elements associated with the construction process, from inception to completion, that means there is an immense amount of knowledge. Human experts are neither easily affordable nor readily available. Thus, using an expert system can help solve this problem. Expert systems can act as the mechanism for storing knowledge and keeping it for future reference.

(Alkass and Harris, 1988; Alkoc and Erbatur, 1998; Levitt, 1987; Minkarah and Ahmed, 1989; Mohan, 1990)

For the above reasons, the transfer of construction expertise becomes important and achieving these tasks through an expert system should be the most appropriate presentation method.

6.3.2 Application of expert systems in the construction industry

Expert systems have already been developed in construction engineering and management in the past decades in the following areas:

- Construction planning (Brandon, 1990; Gray, 1989; Hendrickson et. al., 1987)
- Productivity improvement (Alkoc and Erbatur, 1998 and Bousabaine, 1995)
- Construction scheduling (De La Garza and Ibbs, 1990)
- Cost estimation (Drogemuller and Najjar, 1994)
- Representation of procedure (Gowri and Depanni, 1998)
- Risk analysis (Kanagri, 1987)
- Bidding mark-up (Ahmad and Minkarah, 1988)
- Application on legal aspects (Betts et. al., 1993)
- Environmental management (Bowen-James, 1997)
- Building defects (Mathur and Leng, 1992)
- Building repairs (Kalyanasundaram et. al., 1990)
- Safety management (Hadipriono, 1992)

Brandon (1990) has reported the development of an expert system used at the strategic planning stage of the development process. The system was developed between the University of Salford and the Royal Institution of Chartered Surveyors (QS Division) and funded under the British Government's 'Alvey' IKBS programme.

The development approach was divided into two distinct stages. Stage one was to develop a simple pilot expert system which allows all those involved in the project to become familiar with the new technology and to firm up the brief for Stage two. Stage two was expected to develop one or more expert systems which would form a datum and which would eventually be able to be developed into a commercial product.

The finalised system is divided into four modules, including ‘financial budget’, ‘procurement’, ‘time’ and ‘development appraisal’. The reason is to facilitate the user to choose which aspect that they are interested in. Boussabaine (1995) and Bowen-James (1997) have also broken down their developed system into different modules.

The knowledge acquisition method for this project is interview; multiple experts were interviewed in both the acquisition and validation process. Kalyansundaram et. al. (1990) also adopted the same approach for the knowledge acquisition method for building up REPCON, an expert system for building repairs.

Alkoc and Erbatur (1998) developed SITE EXPERT, an advisory system intended to provide advice on productivity improvement on construction sites. Similar to other expert systems, SITE EXPERT consists of (1) a knowledge-base that represents and stores the experts' knowledge and facts about the construction domain as rules, (2) an inference engine that facilitates a reasoning process to solve a specific problem and (3) a context memory that contains the information about the problem currently being solved and (4) a user interface that inputs and outputs information. The user interface is designed to be as simple as possible because the targeted users are individuals with little computer literacy. It is designed to have totally interactive procedures where the users communicate with the system through a user interface. It provides a textual and graphical interface between the user and the system, also with user-friendly facilities such as on-line help explanation and error recovery.

The knowledge acquisition process of SITE EXPERT includes two phases. The initial phase includes a literature review and iterative prototyping. In the second phase, this knowledge is validated and expanded by interviewing site experts, and again, with iterative prototyping.

The verification procedure for SITE EXPERT is to check and verify the contents of the rules for any discrepancies and errors against the published data. A system is said to be consistent if repeated executions with the same data lead to the same results and conclusions. The aim of validation is to check whether the prototype system has reached a reasonable level of quality at the end of the development stage. It has been done by requesting the domain experts to run the system in order to check whether they are satisfied with the system. Furthermore, the outputs of the SITE EXPERT have been validated on two major construction operations.

The common features of the developed expert system are

- Breakdown of the system into different modules in order to facilitate the users
- Design a user-friendly interface
- Use multiple knowledge acquisition processes, such as developing a prototype and interview with experts in the subject area
- Interviews with targeted users and test by a real case study as the validation procedure of the system
- Check the consistency and accuracy of the rules as the verification procedure of the system

CONBPS has learnt the advantages of the developed system. The development of CONBPS is further discussed in sections 6.5 and 6.6 and the evaluation procedures are discussed in chapter ten.

6.4 Development tool of CONBPS

The aim of this project is to develop an automated process model which lists all the construction activities and their responsible parties. The intention of the model is to be able to provide information to the users on the activities that:

- need to be performed
- the aspects that require special attention
- provide relevant additional information prior to the start of a particular activity

The knowledge stored in the system is derived from relevant literature including regulations and the experience from the practitioners (see section 6.5).

The system should provide the above information via interim reports. Additionally at the end of the project the system should provide a report explaining which tasks have been skipped and the possible consequences.

Expert systems have been employed in numerous advisory tasks where a high degree of decision logic is required in order to offer suitable advice. Such systems are built using tools known as 'expert system shells'. These shells comprise a predefined inference engine that can manipulate the knowledge contained within to solve problems in the area of expertise to which the knowledge appertains. This means that the focus of development is switched from 'how' the knowledge can be used to 'what' knowledge it should contain.

There are numerous expert system shells commercially available. The choice of the most appropriate shell depends upon the requirement of the application. For the CONBPS application the following characteristics were considered desirable:

- The ability to run on a PC computer under the Windows operating system
- Explanation and justification capabilities
- User friendly interface
- The capability to link with other software
- Within the financial resources available for the research project

Several kinds of software such as traditional programming languages, e.g. Visual Basic and C++ and traditional expert system languages, such as LISP, Prolog and Crystal, have been considered.

The use of a traditional programming language has its advantages as it can perform a lot of functions that may not be able to be done by using the commercial package. On the other hand, it takes a long time to build up and it is much more complicated. Therefore, it is difficult to debug. Also, it is difficult to acquire knowledge at the knowledge acquisition stage. It is not economic in terms of time and cost. Besides, if the knowledge is tied up with algorithm, it further impose restriction.

The use of Prolog, Lisp and Crystal will face similar problems as a traditional programming language. On the other hand, it is also difficult to seek information and debug. Although there are the Window-base versions, they are not available in house and it is beyond the financial constraint of the researcher.

The chosen development tool for this model is the 'expert system shell'. An expert system shell is the package designed to support the development of a knowledge-based system. These shells comprise a predefined inference engine that knows how to use the knowledge base to reach conclusions.

The knowledge representation technique and utilities have already been built into these tools. An expert system can be built without having to create the reasoning and data structure components. Thus, expert system shells are easy to use, especially for developing prototype systems

The most suitable expert system shell satisfying these requirements was 'XpertRule' (© Attar Software).

The development environment within XpertRule is a highly graphical environment with an intelligent user interface and extensive on-line help. An XpertRule application is constructed graphically as a hierarchy of chained tasks (displayed on the Map View). A task can consist of a decision tree representing a flow chart controlling procedures, graphical dialogs, procedures, reports or other tasks. Complex knowledge can be structured into a hierarchy of chained tasks (Attar, 1999). The knowledge representation will be further discussed in section 6.6.

6.5 Knowledge acquisition of CONBPS

Knowledge acquisition involves eliciting, analysing and interpreting the knowledge that a human expert uses to solve a particular problem. It was found to be the most important, laborious, ambitious, challenging and time-consuming part of developing an expert system. One important thing in the knowledge acquisition process is to incorporate the knowledge from experts into the system, otherwise, the knowledge is too vague and shallow.

Several investigators have argued that no single methodology for the process of knowledge elicitation has proven universally effective (Hart, 1985; Hofman, 1987; Trimble et. al., 1986). The use of multiple techniques should result in richer systems. The key concern in selecting the correct combination of knowledge acquisition method is to start with looking at the problem-domain characteristics and system-developer resources (De La Garza and Ibbs, 1990).

Figure 6.1 shows the knowledge acquisition process of CONBPS. The box on the left-hand states the title of the knowledge acquisition process and the text in the right-hand side describes the related action. The first four stages are the knowledge acquisition process and these will be discussed in this chapter. The remaining stages are the build-up process of CONBPS and they will be discussed in chapters nine and ten.

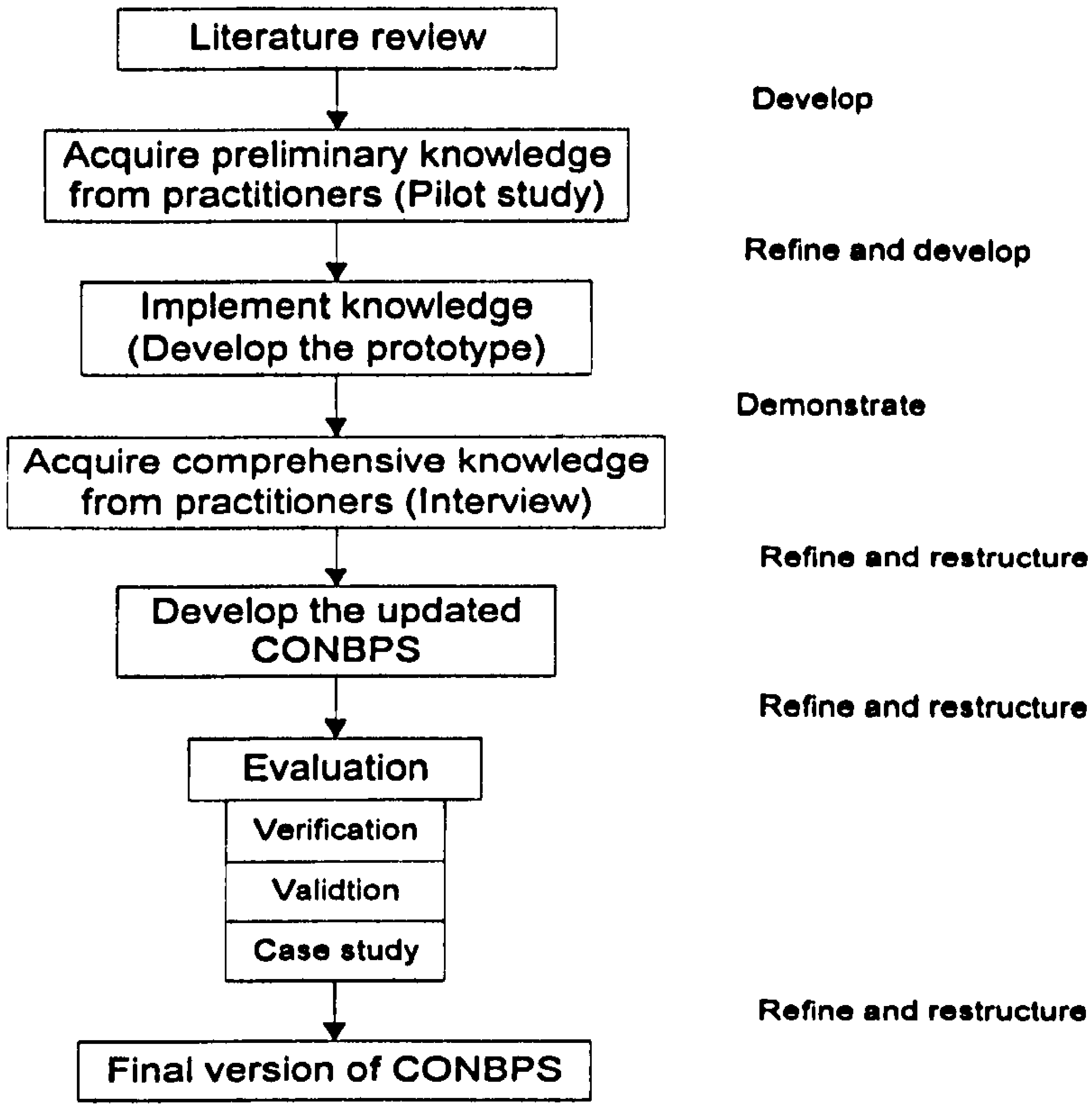


Figure 6.1 Development process of CONBPS

After considering the above issues for the selection of the knowledge acquisition process, the methods to acquire knowledge in this project include four stages:

- Literature reviewing: Reviewing of textbooks, journals and reports etc.
- Survey experts: Sending out the theoretical framework of CONBPS to practitioners for comment
- Prototyping: Offering the developed prototype model for criticism
- Interview: Semi-structured interview with experts for abstracting experts' knowledge and experience

Literature review

The aim of the literature review process in this project is to develop the framework of the construction process model and it has been stated clearly in chapter five.

Survey experts

The second stage of knowledge acquisition is by sending out the theoretical framework of CONBPS for practitioners to comment on. The literature review and the development of CONBPS have been shown in figure 5.1. This becomes the pilot survey of this project and it has been discussed in section 7.2.

Prototyping

Prototyping means the process of developing a developed prototype model for criticism and gradually improve it by allowing the experts to comment. It involves the development of a knowledge base at an early stage during knowledge elicitation and the demonstration of this to the domain expert. The basis of this technique is that it is easier for a domain expert to say how the approach of an existing system is incorrect than to state what the correct approach should be in isolation.

For the current project, the prototype development started after receiving the comments of representatives from the Housing Associations, and the preliminary system was developed. Section 6.7 has clearly stated the operation of the prototype of CONBPS.

Interview

The final stage of knowledge acquisition is to interview the experts and it is the major survey of this project. Interviewing is the most common method of fact-finding in the system analysis for computer systems. The method for conducting the interview in this research is a semi-structure method. It is because a semi-structured interview is more flexible than a structured interview. Also it has more guidelines and control than an unstructured interview. An unstructured interview facilitates the description of the domain in a way that is easy for the expert to understand. However, the data acquired is often unrelated and difficult to integrate due to the lack of structure. It may not allow gathering of specific knowledge and takes time and training to do well. On the other hand, structured interviews have the advantages of forcing the participants to be involved in the interview and being very goal-directed. It is more easy to obtain the knowledge in a systematic and organised way. However, it also constrains the flexibility of interviewees and limits the comments from the practitioners.

In the semi-structured method, the questions asked are of the open-ended type, in which the wording of the question is specified but the wording of the response is left to the respondent. The interviewer can seek further elaboration of a particular area by asking further questions.

The research method and research findings of this knowledge acquisition have been further discussed in sections 7.2, 7.3, 8.2, 8.3 and 8.4

6.6 Knowledge representation of CONBPS

The 'decision trees' are the main knowledge representation method in 'XpertRule' and they were chosen as the knowledge representation method in this project. CONBPS is an expert system which models the construction process and the activities are listed as a sequence. If it is presented in a tree, it is easier to identify the errors.

Besides, it is also more convenient for the practitioners to comment as they can see the flow of logic in a diagram.

6.6.1 Description of decision tree

A decision tree is a hierarchically arranged semantic network and is closely related to a decision table. It is composed of nodes and branches that represent decisions or outcomes. Nodes represent connecting between the tree and branch. The node at the top of the tree that has no parent is called the root node. Nodes with no children are called leaves. The leaf nodes of a decision tree represent all the possible solutions that can be derived from the tree. The nodes are referred to as answer nodes, and all other nodes in the tree are referred to as decision nodes. Each decision node represents a question or decision that when answered or decided, determines the appropriate branch of the decision tree to follow (Awad, 1996; Giarrantano and Riley, 1994).

6.6.2 Advantages of decision tree

Representation method

The representation of a decision tree is both compact and efficient, far better than other forms used by conventional rule based systems. The traditional programming technique, which may consist of many IF... AND... OR... THEN... ELSE program statements, is difficult to debug and test all possible decision paths, let alone to optimise the flow to maximise performance. Such programs, over time, become impossible to maintain.

On the other hand, a 'decision tree' shows decision-making logic in an easy to understand graphical form for capturing, structuring, representing and maintaining knowledge. The graphical nature makes them more understandable and the inference form trees can be orders of magnitude faster than an inference form rule because of the elimination of the need to search rule bases. A tree can represent many 'rules' and when you execute the logic by following a path down it, you are effectively bypassing rules that are not relevant to the case in hand. You do not have to look at every rule to see if it 'fires' and you also take the shortest route to the correct outcome.

Knowledge acquisition

Using 'decision tree' as a method of knowledge representation also has an advantage on knowledge acquisition, which is acknowledged as the bottleneck of expert system development.

XpertRule is a specialised system for capturing knowledge and developing intelligent applications:

- A graphical development environment that makes it easy to prototype, build, maintain and test knowledge based systems
- Solutions can be delivered on Microsoft Windows PC's and networks and on the Internet / Intranets using the XpertRun run time

Knowledge structuring

Furthermore, a decision tree also has an advance in knowledge structuring. The lack of a modelling methodology for decomposing a large application into a hierarchical structure of rule sets represent a major difficulty in building traditional knowledge based systems. Without the structuring of rule sets, developing a rule base for a large application becomes difficult. This problem is compounded by the lack of formal ways of structuring within the rule base 'inference engine'. Several ad hoc methods of structuring rule sets have been put forward, such as spider diagrams and concept maps. These methodologies aim to model the application by establishing a hierarchy of concepts, each concept with a corresponding rule set or a rule base. The developer must then add control rules, agendas or demons to force the flow of the inference engine, to correspond to the structuring of concepts.

XpertRule enables highly complex KBS applications to structure into more manageable units of knowledge – each unit being called a 'Task' – and to be able to build and visualise the overall structure with a tasks 'Map'.

System testing

Different from a process chart, decision trees can be tested immediately. The XpertRun Inference Engine can be used to 'run' the application at any time. Automatic default user dialogs are generated, enabling the testing of prototypes with no developer effort. Nesting of trees can be used to relate sub-tasks to a main task. Therefore, any errors can be found and corrected immediately.

6.6.3 Knowledge representation

The CONBPS is divided into twelve modules which represent each construction stage. The reason for dividing the modules in this way is to assist the user. The user can choose the modules depending on which construction stage they are currently using.

The first four construction stages have been developed in the prototype system. Figure 6.2 has shown the map of the first four stages.

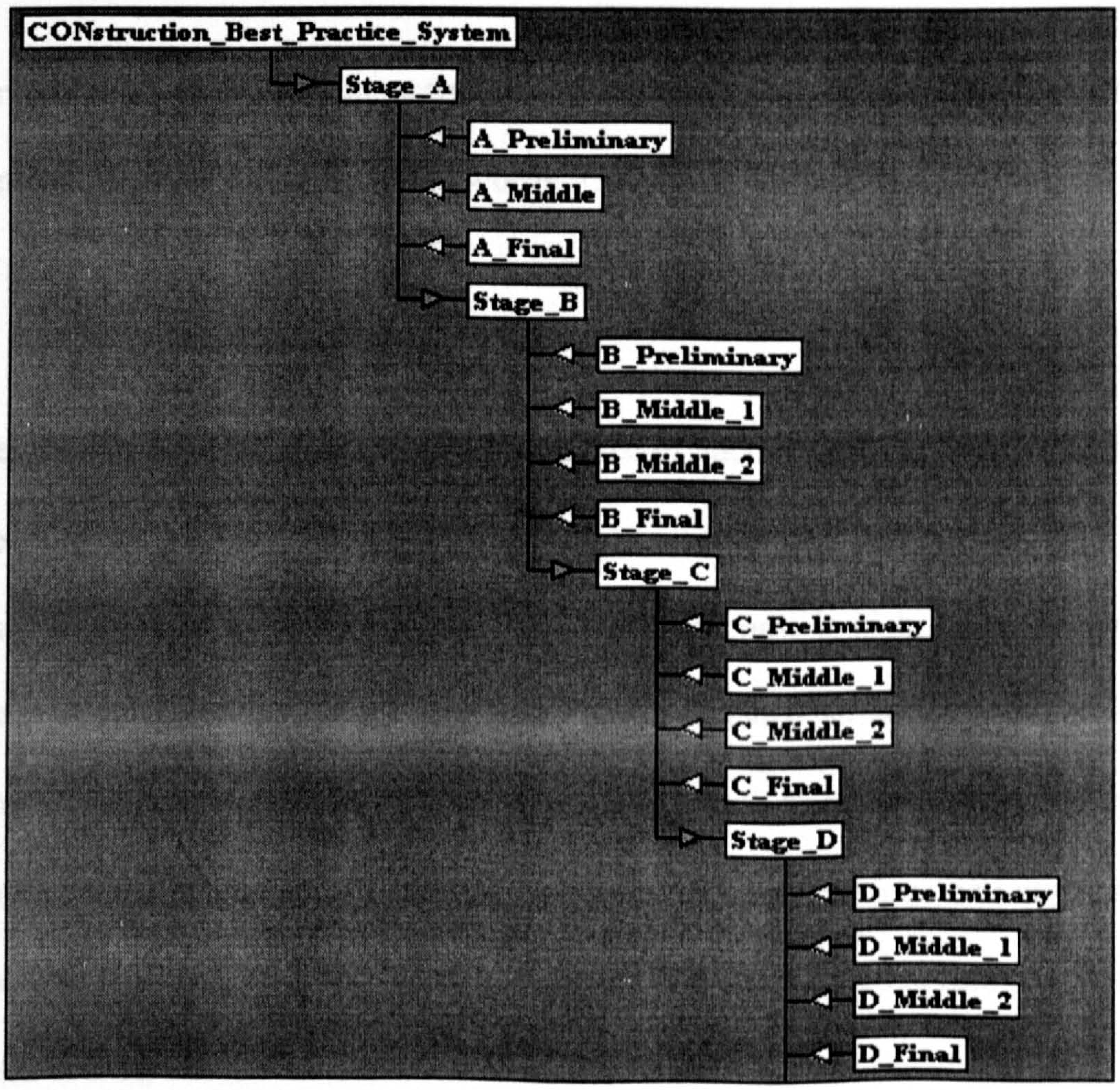


Figure 6.2 Map of prototype of CONBPS

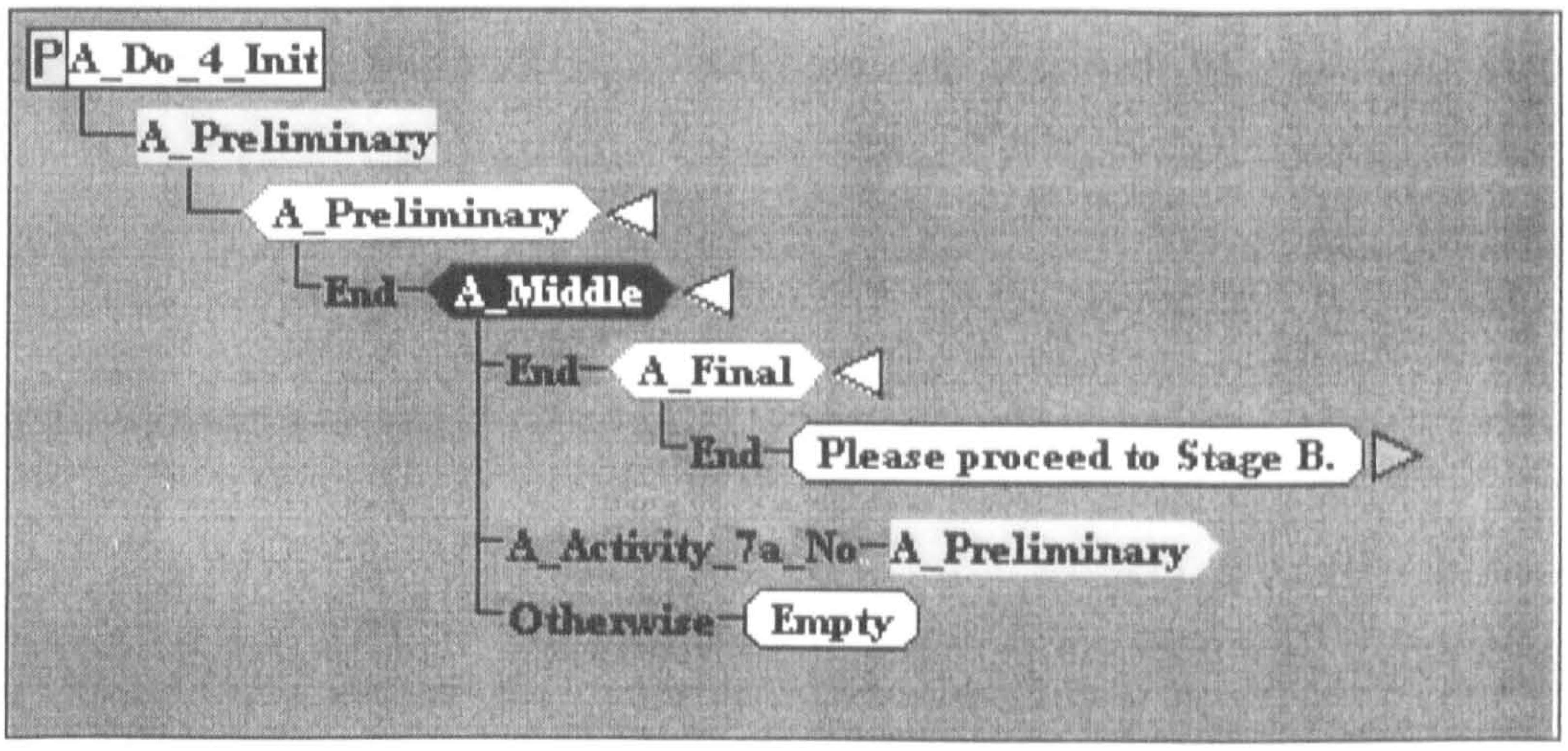
The 'Map' is often the central view of an expert system. As well as viewing the chaining hierarchy, the Map view allows the developer to make and remove forward and backward chaining links.

The inference engine of this system uses forward chaining, that is proceeding from stage A to stage B then stage C. Each stage is identified as a 'task' in the system. As there are too many activities in each construction stage, therefore, they are divided into three or four sections. The reason for dividing activities into smaller sections is solely to facilitate the build-up and debugging procedure. These sub-sections are linked to the related construction stage by backward chaining.

The relationships between the activities are sequential and semi-static. The activities are in a sequential order. In order words, CONBPS will ask the user whether they have started activity two after they has completed activity one.

There are two possible outcomes for the choice of each activity. The first outcome is proceeding to the next activity if the user has completed this activity and it has explained in the previous paragraph. The second outcome is if the user answers 'no' to the particular activity. If the user has not yet finished an activity, the 'reminder statement' will appear and it will loop the activity back to the previous activity. The system would not proceed to the next activity until the previous activity has been completed. It aims at ensuring every activity has been completed before proceeding to the next activity.

The decision tree of each individual stage will be discussed in the following section. Figure 6.3 shows the decision tree for stage A and figures 6.4 to 6.6 show the decision tree for each section in stage A.



Remark: A_Preliminary: Activities 1 to 5a, A_Middle: Activities 6 to 9, A_Final: Activities 10 to 13. The description of the activities is shown in appendix 2

Figure 6.3 Decision tree of Stage A

Basically, the operation of the system takes place within each section. The system proceeds to the next section automatically if the activities in one section have been finished.

In certain situations, if the answer to an activity is 'no' then it needs to loop back to a certain activity which is not in the same section, therefore, some rules are needed to be set in the overall decision tree. For example, if the answer to activity 7a is 'no', it needs to loop back to activity 2. As activity 2 is in the 'Preliminary section' and activity 7a is in the 'Middle section', therefore, a loop needs to be set up between these two sections. Besides, there is the loop within the 'Preliminary section'. If the answer for activity 4 is 'no', it should loop back to activity 2. In order to achieve this function, a 'procedure' function has been added at the beginning of the 'Preliminary section'.

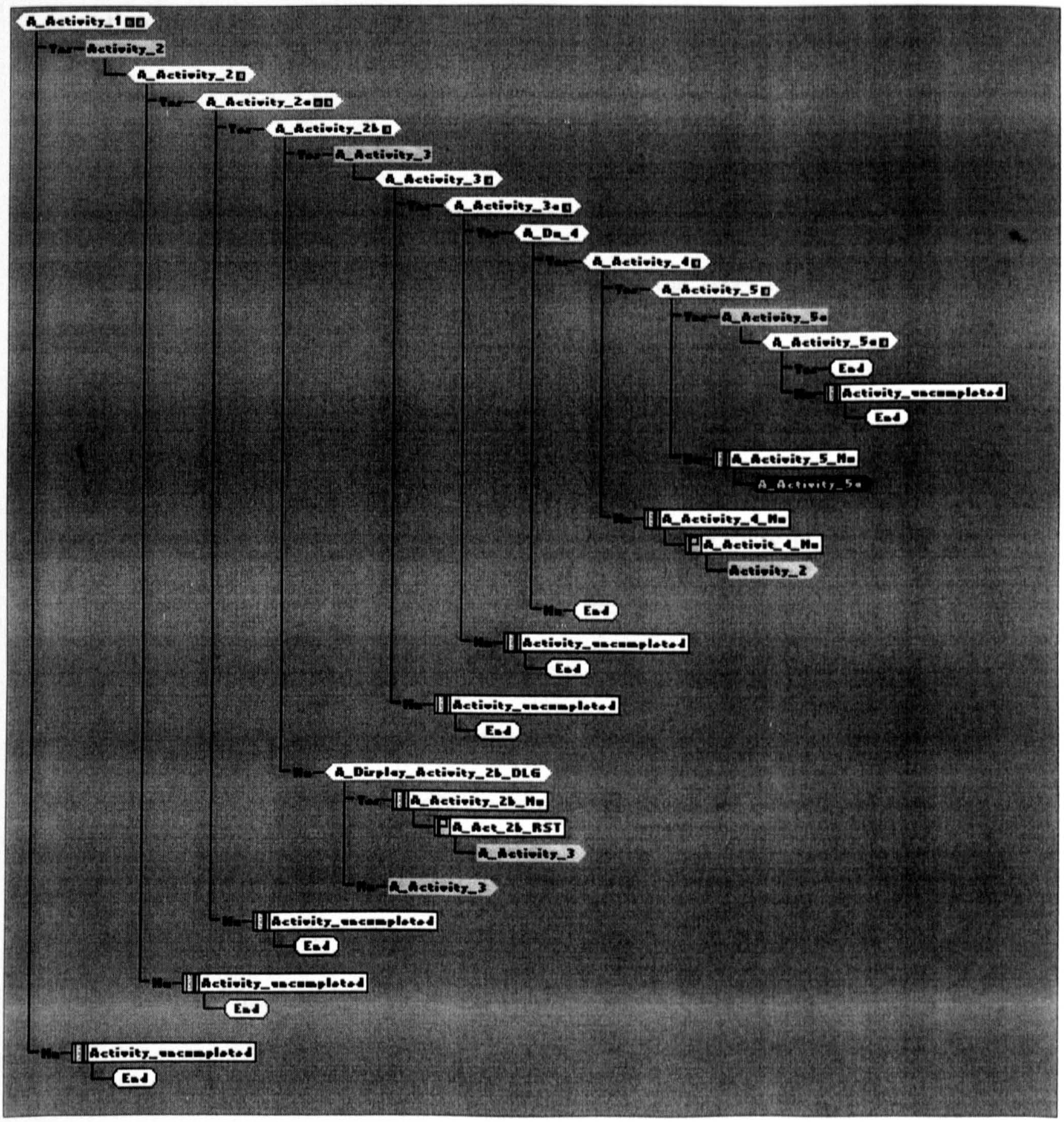


Figure 6.4 Decision tree of Stage A – Preliminary section

Figure 6.4 shows the decision tree for the preliminary section. Each activity is represented in one box; the text of each activity is described in an attached 'dialogue box'. If the answer to an activity is 'yes', it will proceed to the next activity. If the answer to an activity is 'no', it will proceed to an 'Activity uncompleted' statement. For certain activities, like activity 4 and 5a, if the answer is 'no', the system will have special advice instead of simply showing an 'Activity uncompleted' statement. The operation of the system will be discussed in section 6.7 in greater detail.

In order to achieve some looping or setting of the activities, some 'procedures' needed to be set. In order to differentiate, a 'P' has been shown in the box (for example, within activity 4_No). Under certain circumstances, the label is attached with the activity in order to perform certain functions; this is shown on the grey colour box in the decision tree.

Each activity is represented in one box; the text of each activity is described in an attached 'dialogue box'. A 'dialogue box' is the box which shows the text. For example, the 'Activity Uncompleted' in figure 6.4 is the 'dialogue box'. If the answer to an activity is 'yes', it will proceed to the next activity. If the answer to an activity is 'no', it will proceed to the 'Activity uncompleted' statement. For certain activities, like activity 4 and 5a, if the answer is 'no', the system will have special advice instead of simply showing an 'Activity uncompleted' statement. The operation of the system will be discussed in section 6.7 in greater detail.

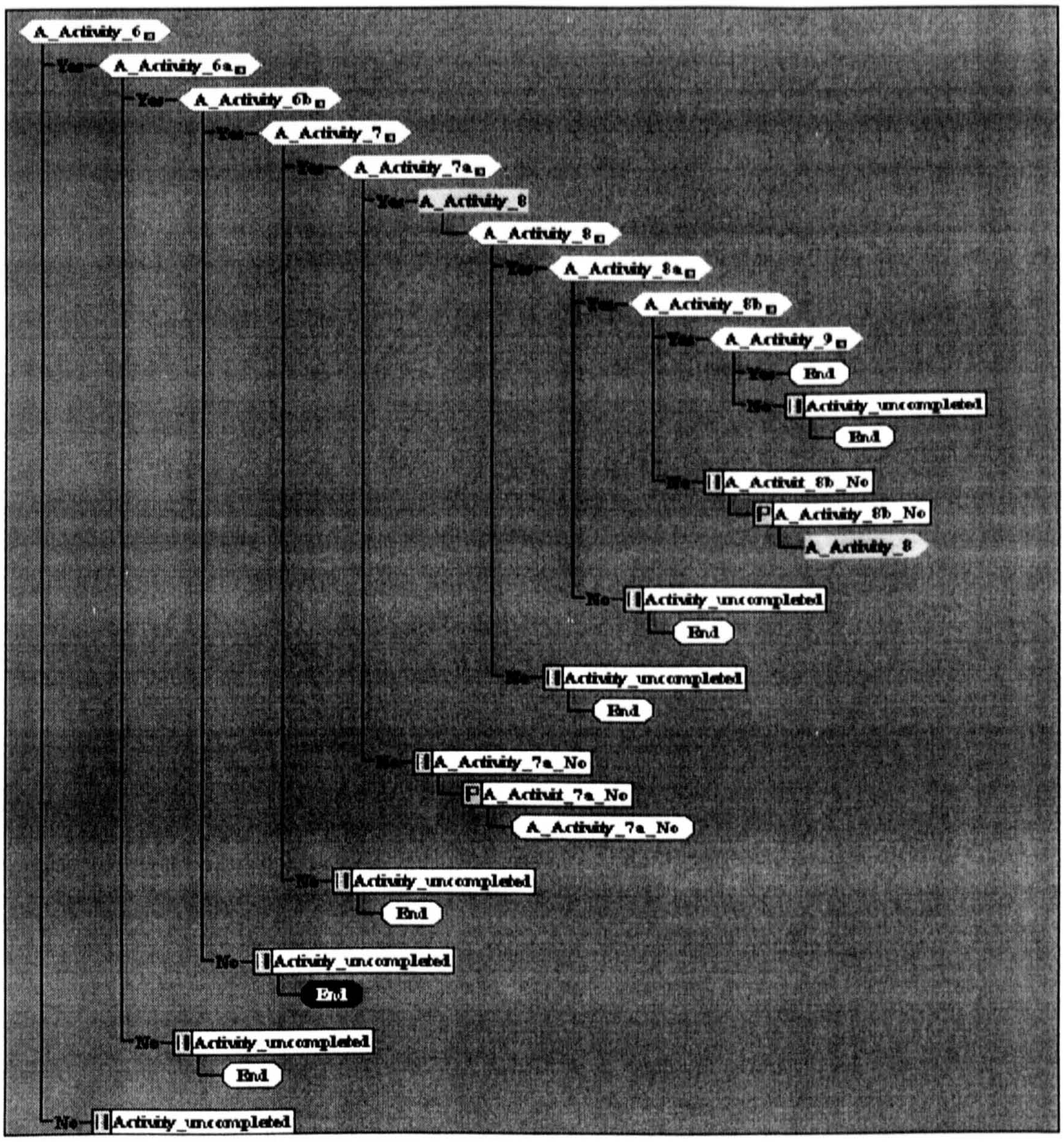


Figure 6.5 Decision tree of Stage A – Middle section

Figure 6.5 shows the decision tree for the middle section. The operation of the middle section is simpler than the preliminary section. There is only one loop between activity 8 and 8b. This loop is to indicate that if the answer to activity 8b is 'no', then it should go back to activity 8.

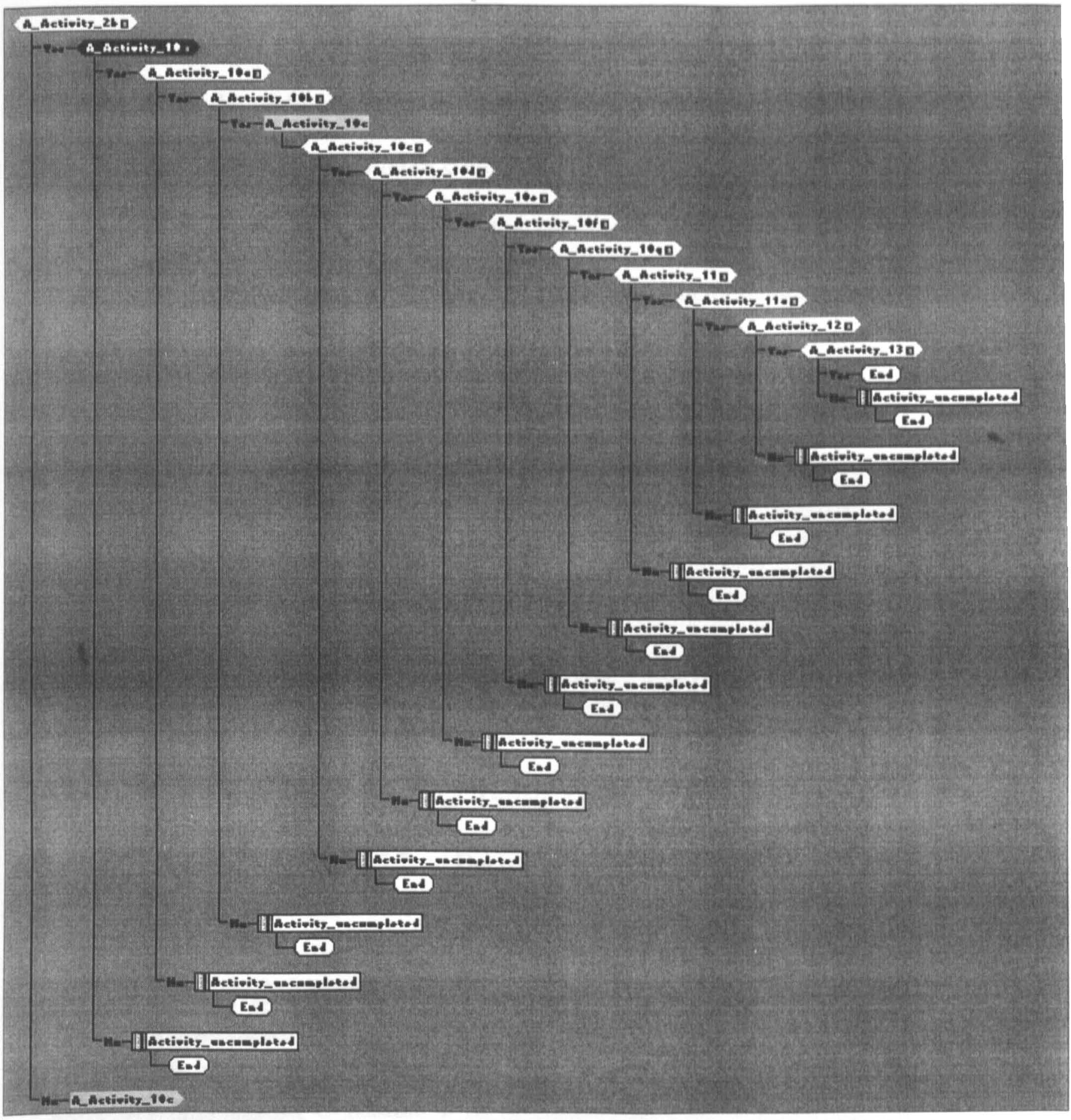
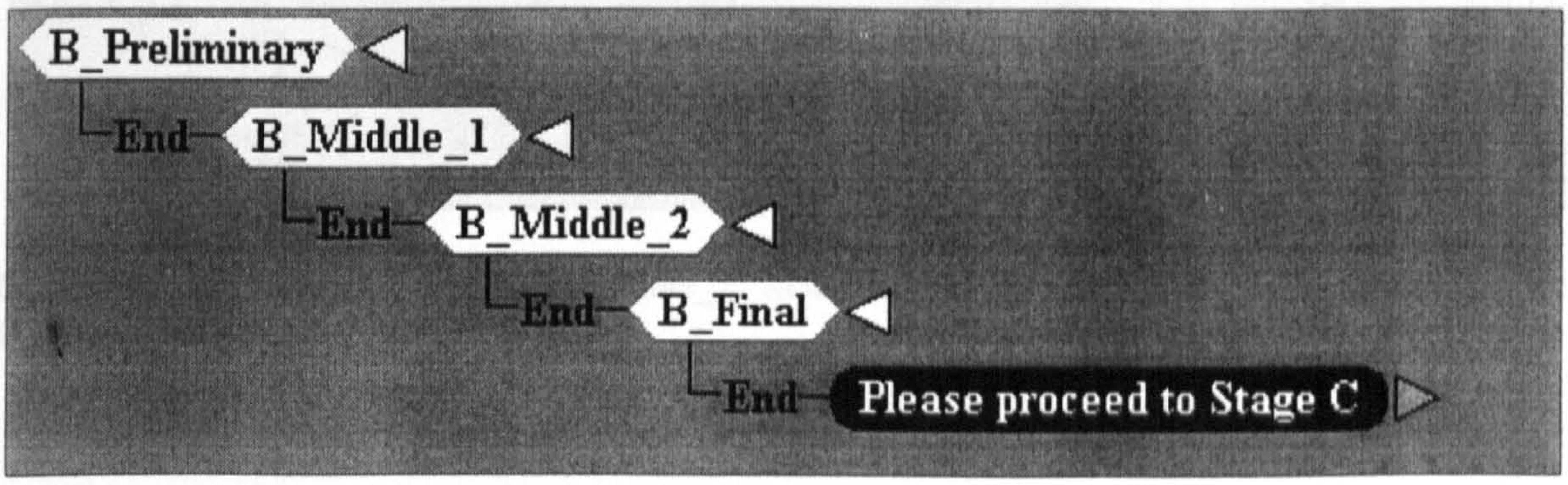


Figure 6.6 Decision tree of Stage A – Final section

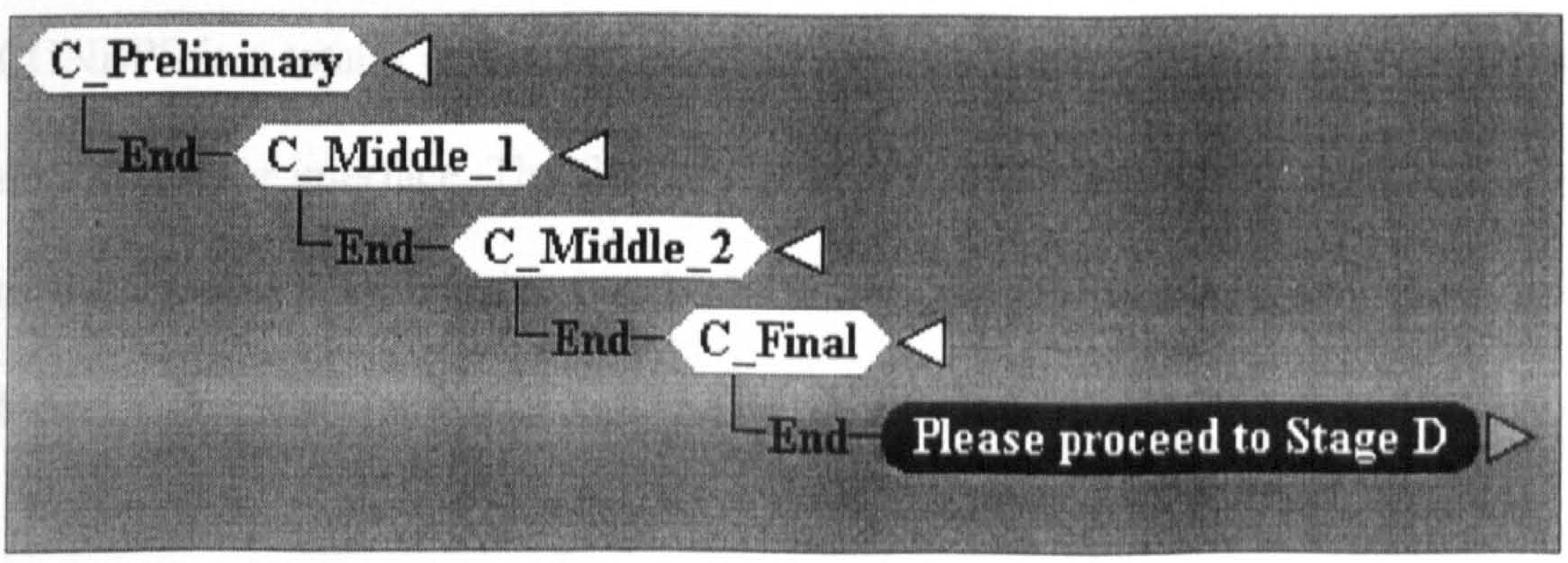
Figure 6.6 shows the decision tree for the 'Final section' of stage A. If the response to activity 2b is 'no', then it ignores 10a and 10b, therefore, some setting has been identified in the 'Final section' decision tree. The label of 'A_Activity_2b' has been added in front of 'A_Activity_10'. If the answer to 'A_Activity_2b' is 'no', it instructs the system to go directly to 10c.

Figures 6.7, 6.8 and 6.9 are the decision trees for stages B, C and D. As there is no looping across the sections, therefore, it is simpler than the decision tree for stage A. On the other hand, stage D is more complicated and there is a lot of looping among different sections. As the looping among the sections has been discussed in 'Stage A', it will not be repeated in this stage. The decision trees of the other stages are listed in appendix three.



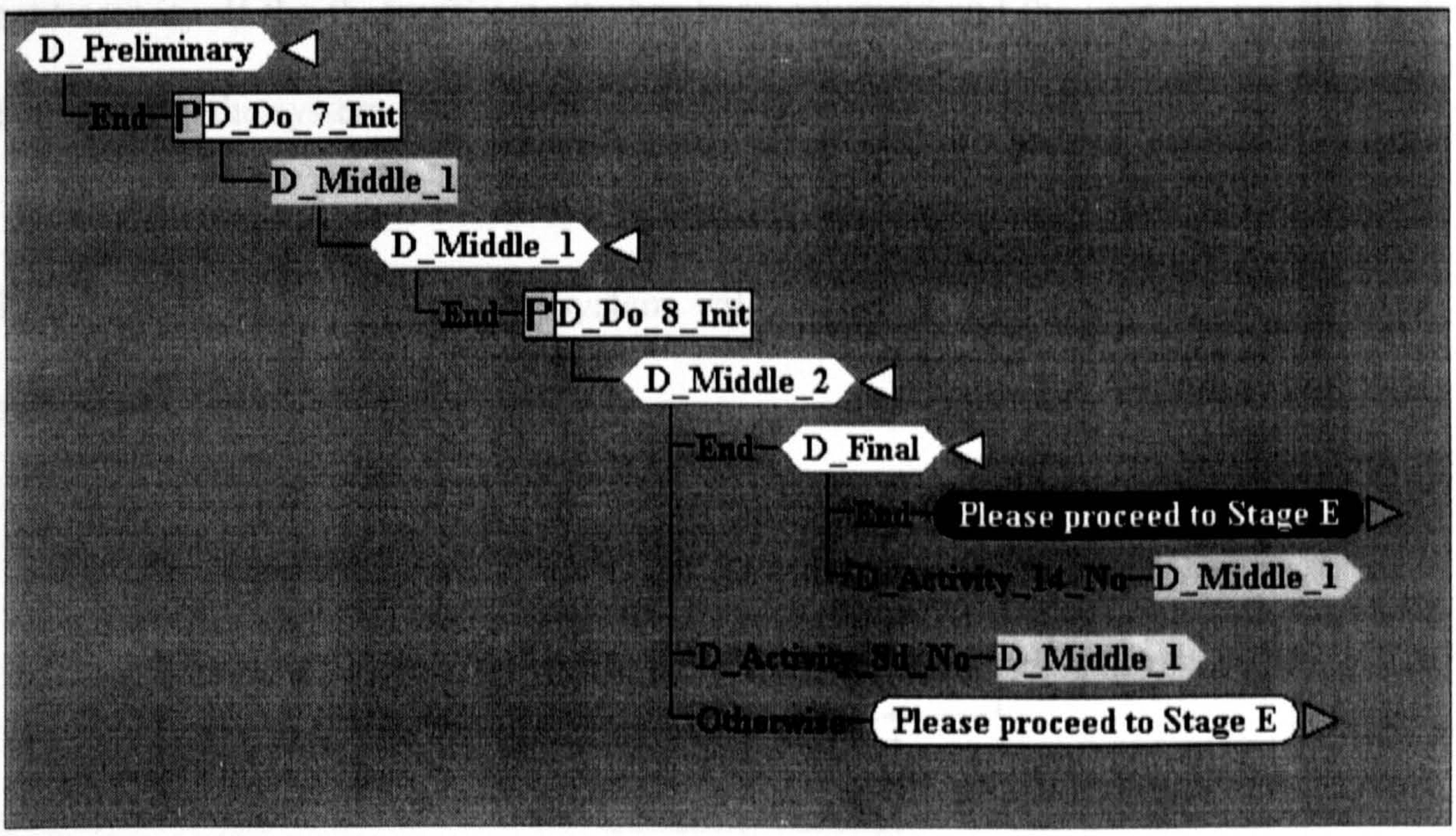
B_Preliminary: Activities 1 to 5, B_Middle_1: Activities 6 to 10e, B_Middle_2: Activities 11 to 15b; B_Final: Activities 16 to 20

Figure 6.7 Decision tree of Stage B



C_Preliminary: Activities 1 to 5b, C_Middle_1: Activities 6 to 10c, C_Middle_2: Activities 11 to 15b; C_Final: Activities 16 to 20

Figure 6.8 Decision tree of Stage C



D_Preliminary: Activities 1 to 5, D_Middle_1: Activities 6 to 7c, D_Middle_2: Activities 8 to 10; D_Final: Activities 11 to 15

Figure 6.9 Decision tree of Stage D

6.7 Operation of CONBPS

CONBPS is a totally interactive procedure where users communicate with the system through a user interface. The first five levels (from the knowledge acquisition process to the CONBPS knowledge base) reflect the process of developing the knowledge base.

The lower part of figure 6.10 shows the operation of CONBPS. CONBPS states the construction activity and asks whether the user has finished the task described. If the user wants more information, then it will link to the explanatory facilities and provide more information. If the users do not ask for more information, it will continue to the next activity. If the 'hotspot' activity has been achieved and the user has not finished that activity, the system will loop back and re-start the mini-cycle again.

The detailed description of the system will be further discussed in the following paragraphs.

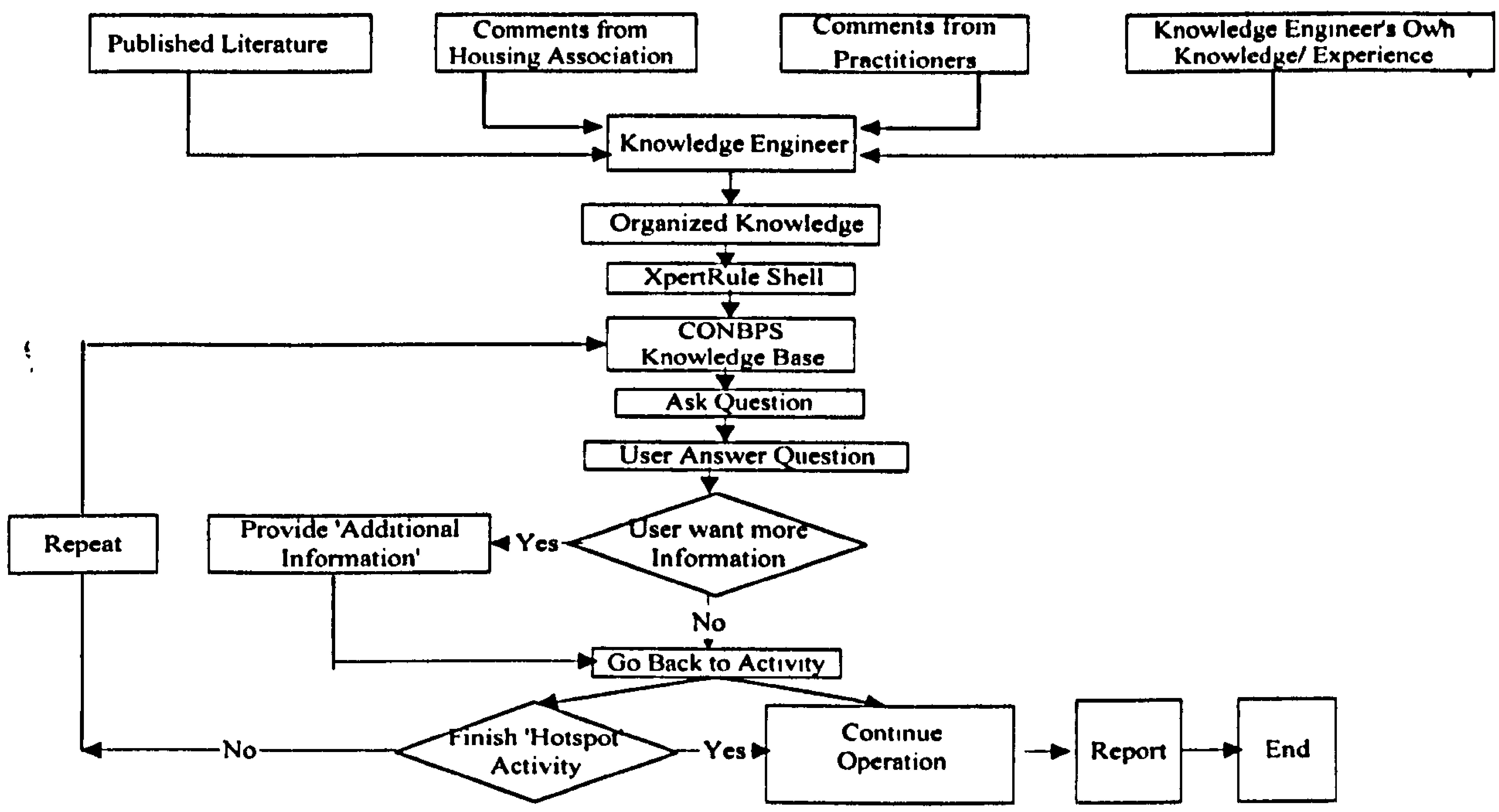


Figure 6.10 Operation of CONBPS

Before proceeding to the modules which describe the design and construction stages, an introduction is included. The first screen is the introductory page (see figure 6.11).

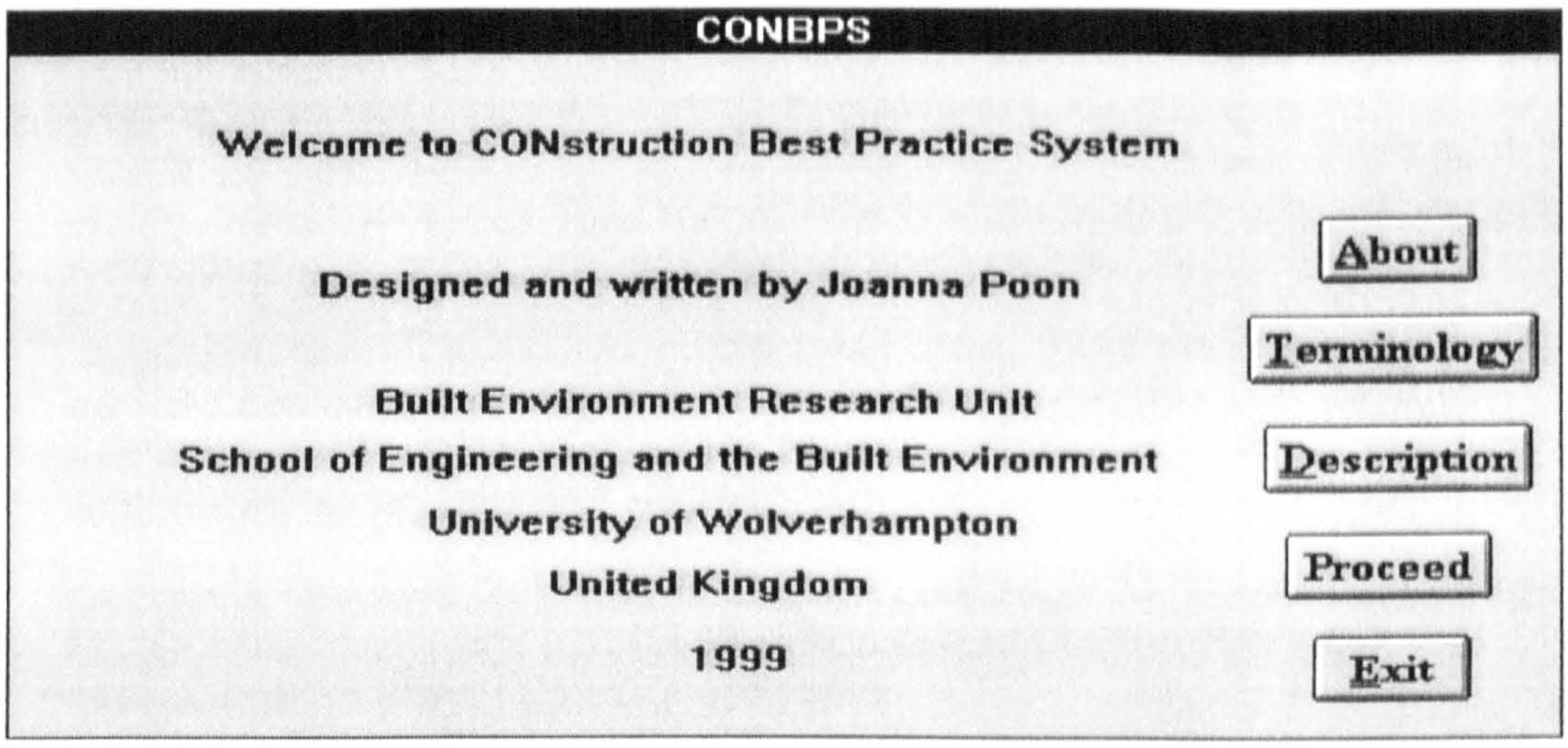


Figure 6.11 Introductory screen of CONBPS

If the user presses the icon 'About' in the first screen, it will link to the screen which briefly describes CONBPS (see figure 6.12). The icon 'Terminology' is linked to the information of certain important terminology (see figure 6.13) and the 'Description' is designed to show the general description of the CONBPS (see figure 6.14). If the user presses 'Exit', the operation of the system will be ended.

If the user presses 'OK' on these screens, the system will go back to the introductory screen (figure 6.11) and the user can choose the other options.

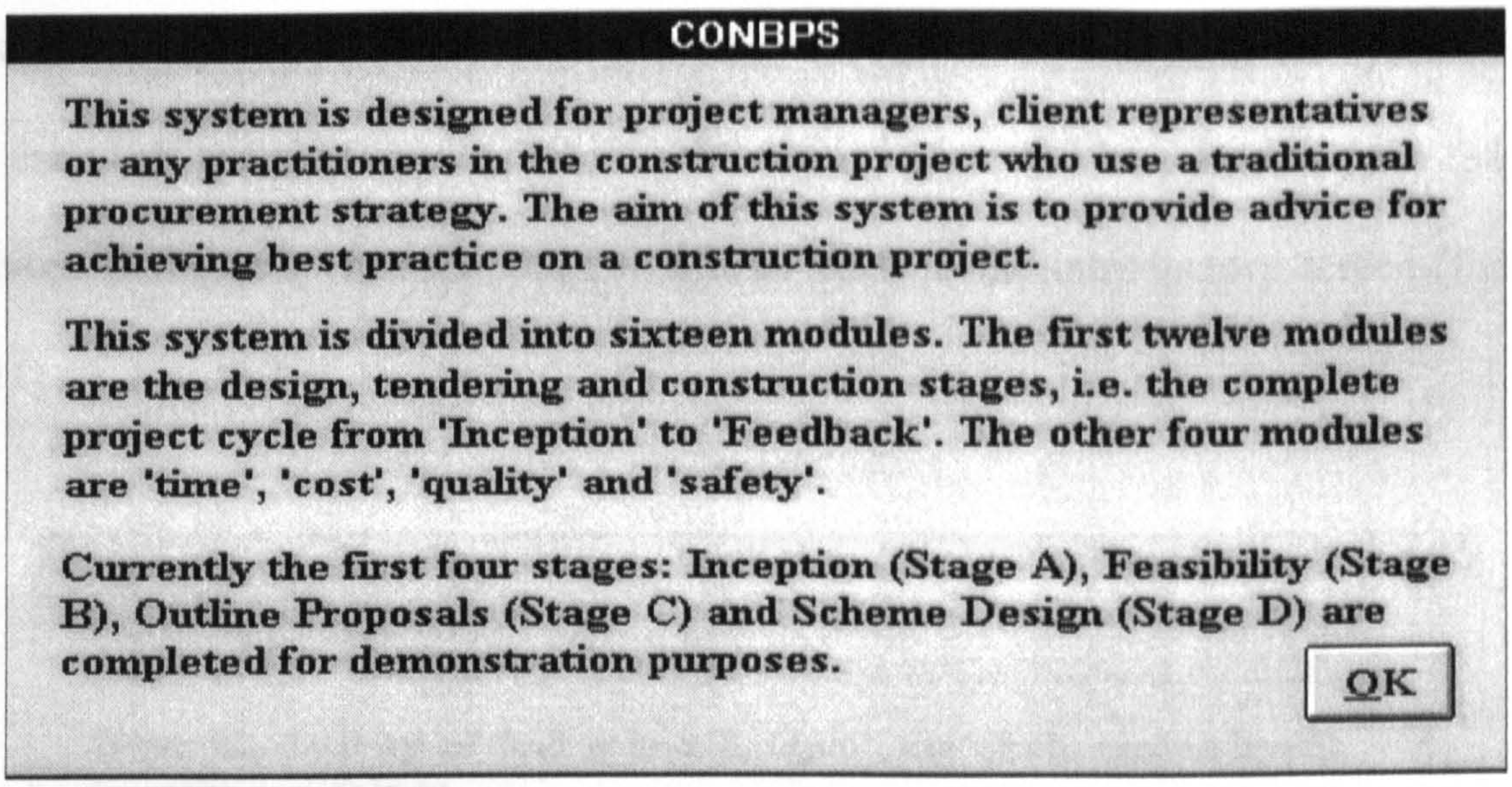


Figure 6.12 The icon 'About' of CONBPS

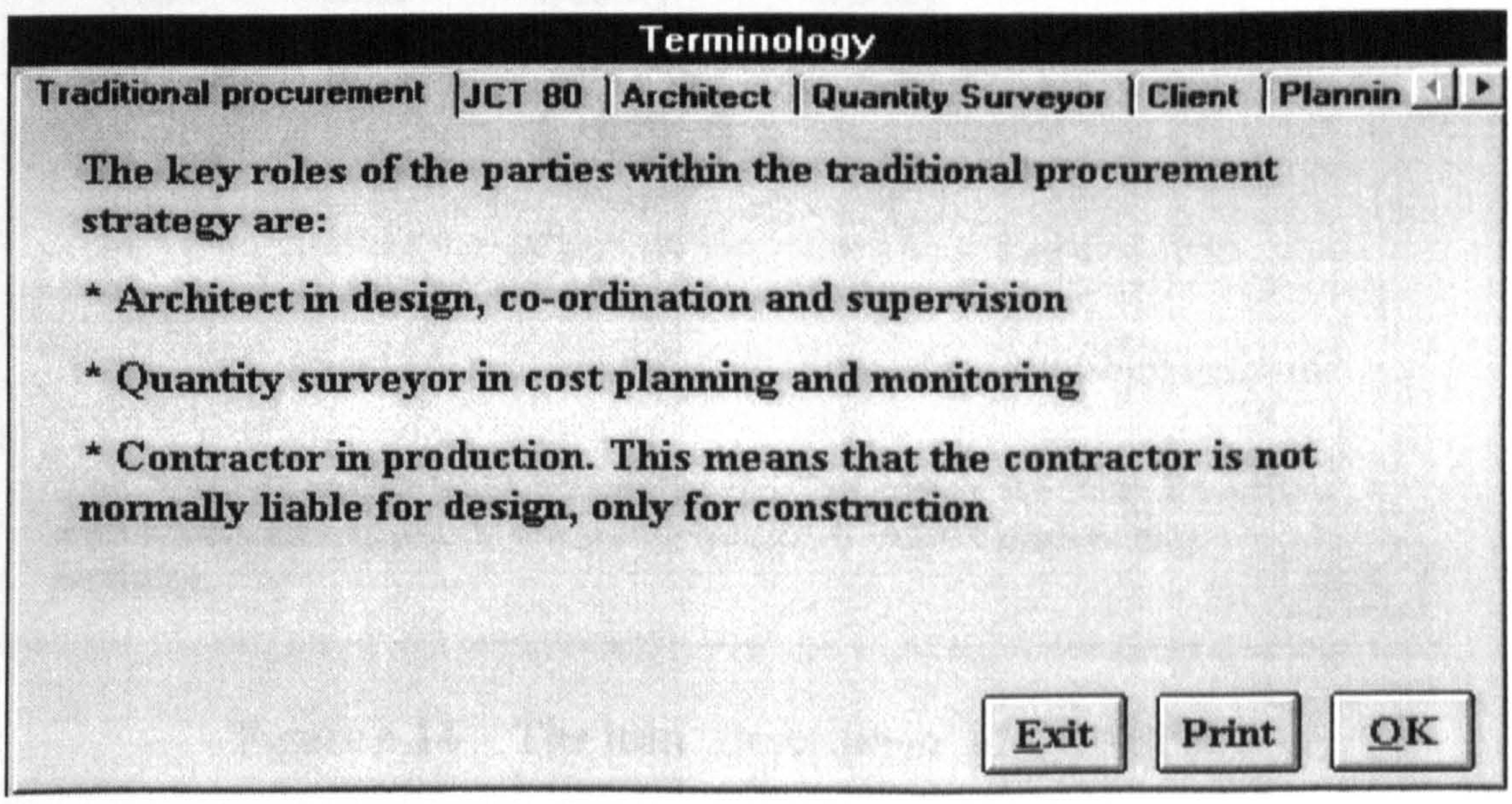


Figure 6.13 Terminology – Traditional procurement strategy

The 'Terminology' is the important element that is preferred to provide a clear definition before starting the operation of the system. These include 'traditional procurement', 'JCT 80', 'architect', 'quantity surveyor', 'client', 'planning supervisor' and 'contractor'. The screen of 'traditional procurement strategy' has been printed as example (see figure 6.13).

If the user presses 'Exit' on the terminology screen, the operation of the system will be ended. If the user chooses 'Print', the current page will be printed on the linked printer. If the user chooses 'OK', it will go back to the introductory screen (figure 6.11).

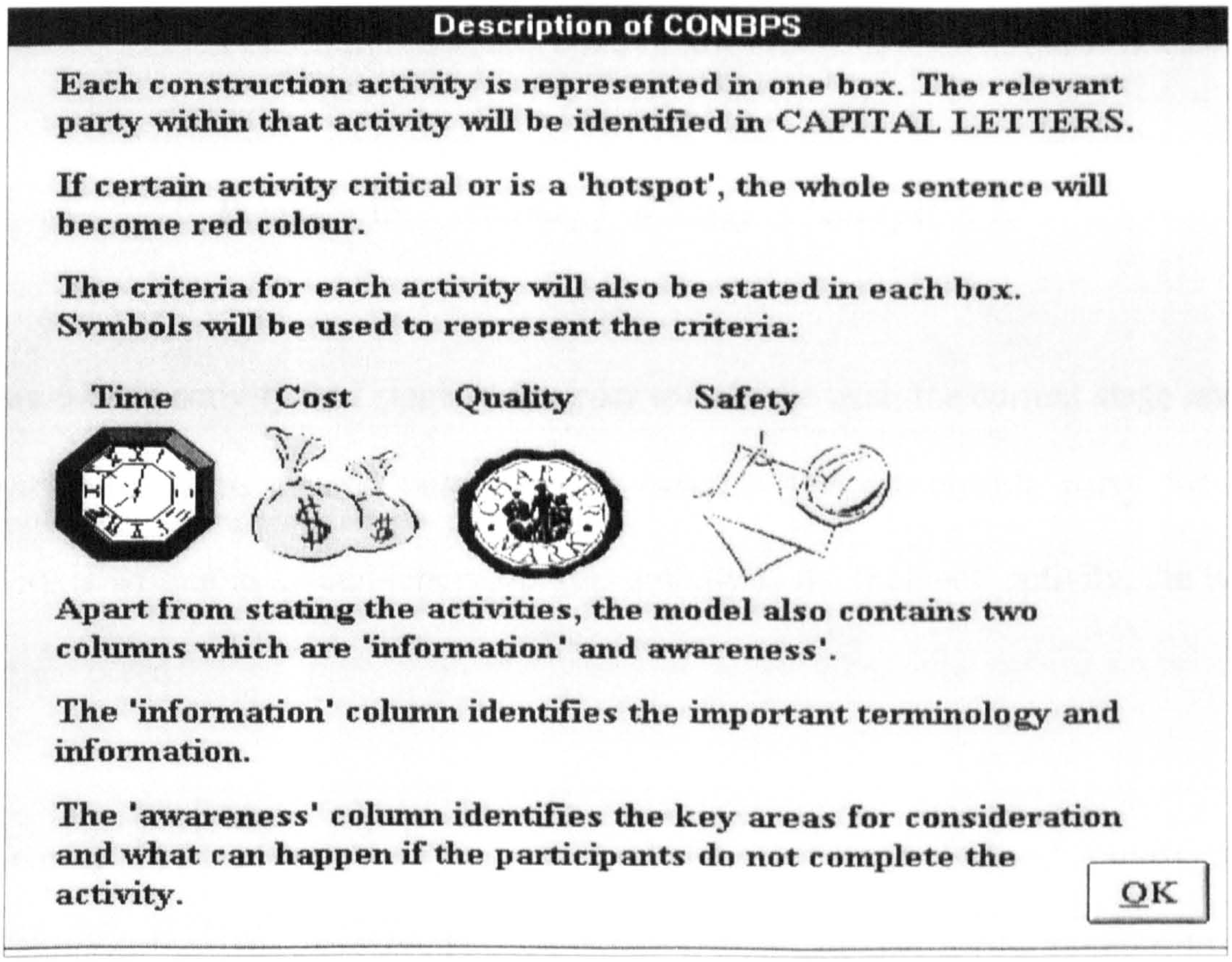


Figure 6.14 The icon 'Description' of CONBPS

Figure 6.14 is the description screen of the system. As with the previous screen, the system will go back to the introductory page (figure 6.11) if the user presses 'OK'.

After describing the introductory stage, the next section is to describe the design and construction stage.

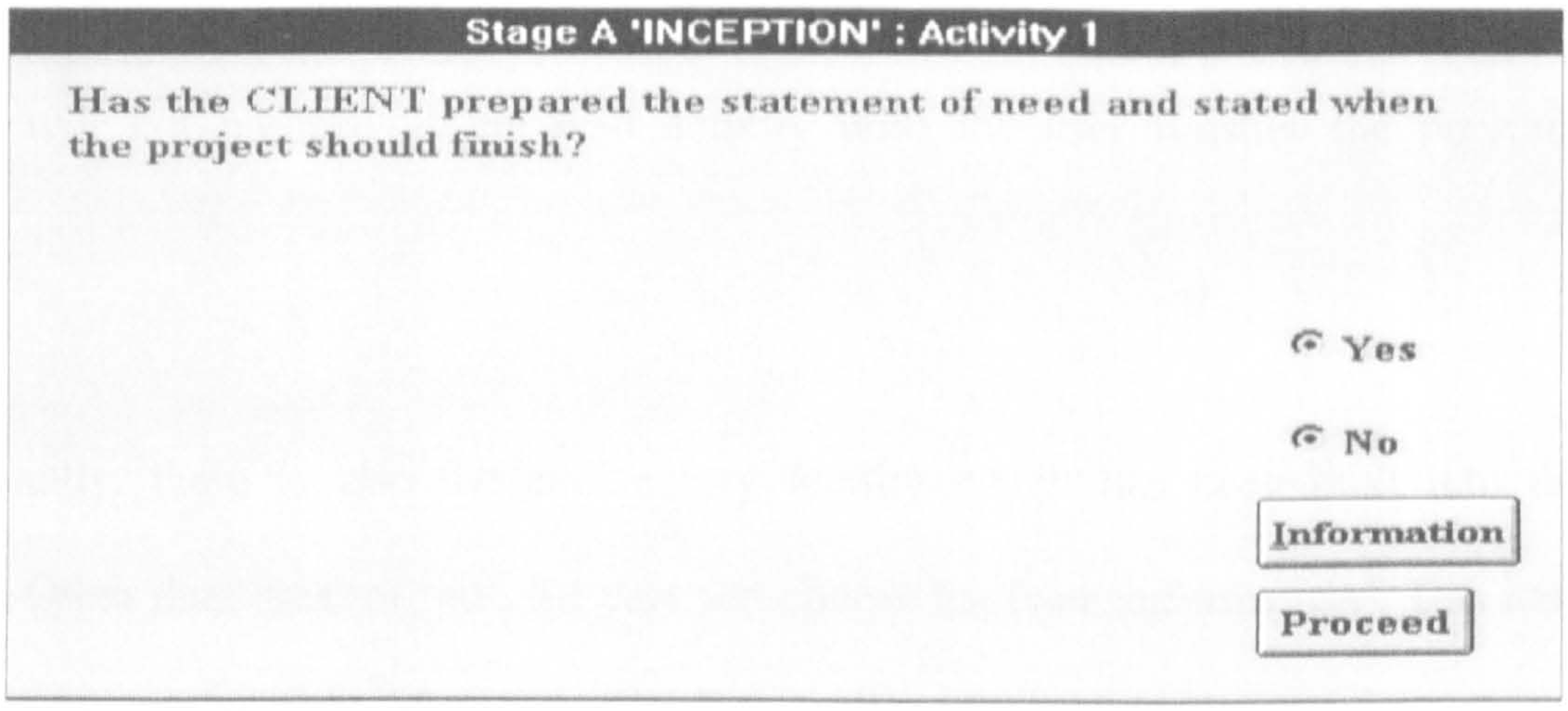


Figure 6.15 Activity 1 of Stage A 'Inception A'

Figure 6.15 is activity 1 of stage A. In order to help the user, the current stage and the activity have been clearly stated in each screen. The responsible party for each activity is written in capital letters. As this activity is the 'hotspot' activity, the whole sentence is red.

If the user chooses 'yes', the system will continue and go to the next activity. If the user chooses 'no', the 'Activity Uncompleted' screen will appear (see figure 6.16).

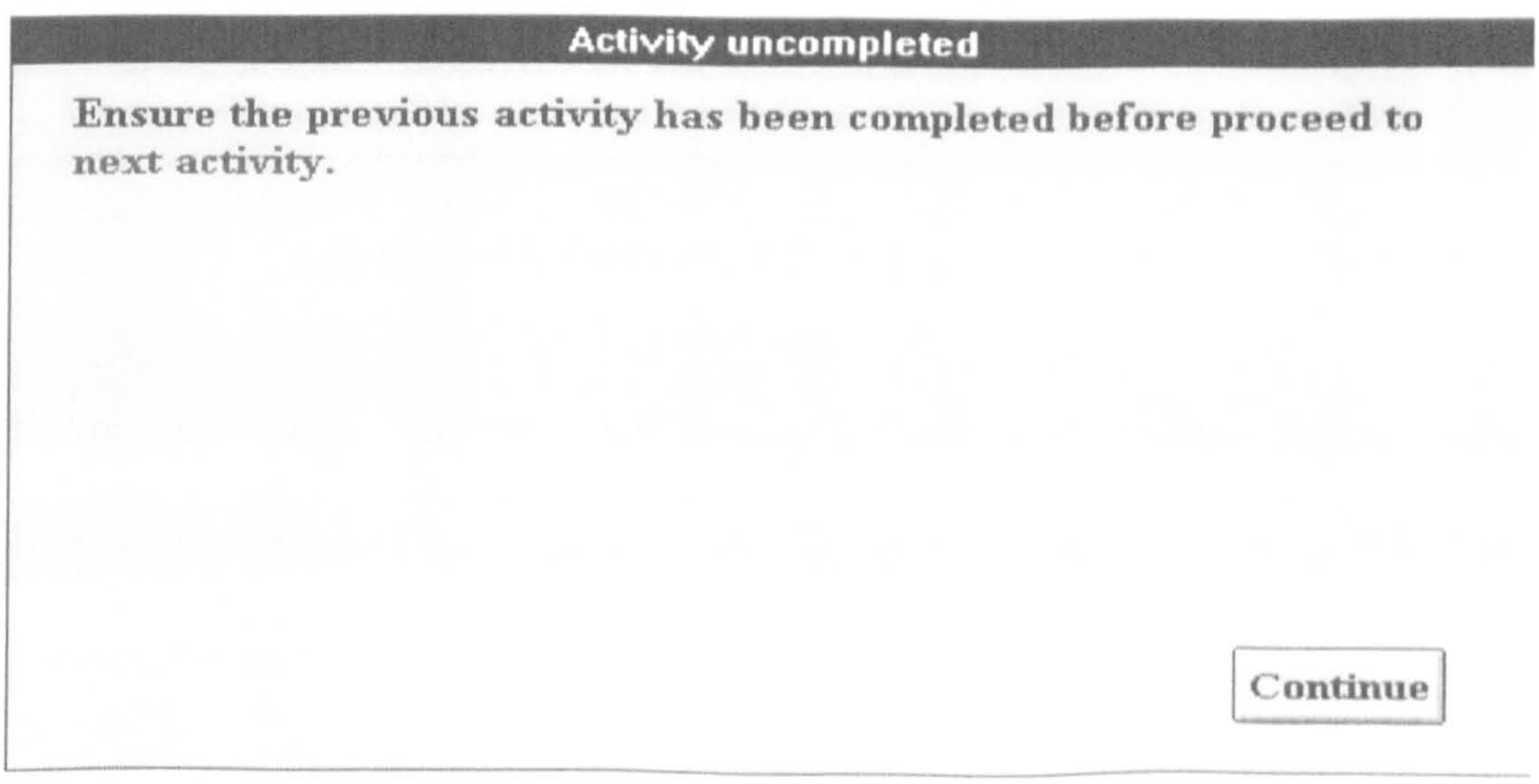


Figure 6.16 Activity uncompleted

If the user presses 'Continue', it will loop back and ask the same question again. The system will not proceed to the next activity until the user finishes the previous activity.

Additionally, there is also the explanatory facility which has been built into the system. Other than 'yes' or 'no', the user can choose the icon 'information'. This icon provides an explanation of the terminology and additional information about the project.

If the user chooses 'Information', it will go to the 'Additional Information' screen (see figure 6.17).

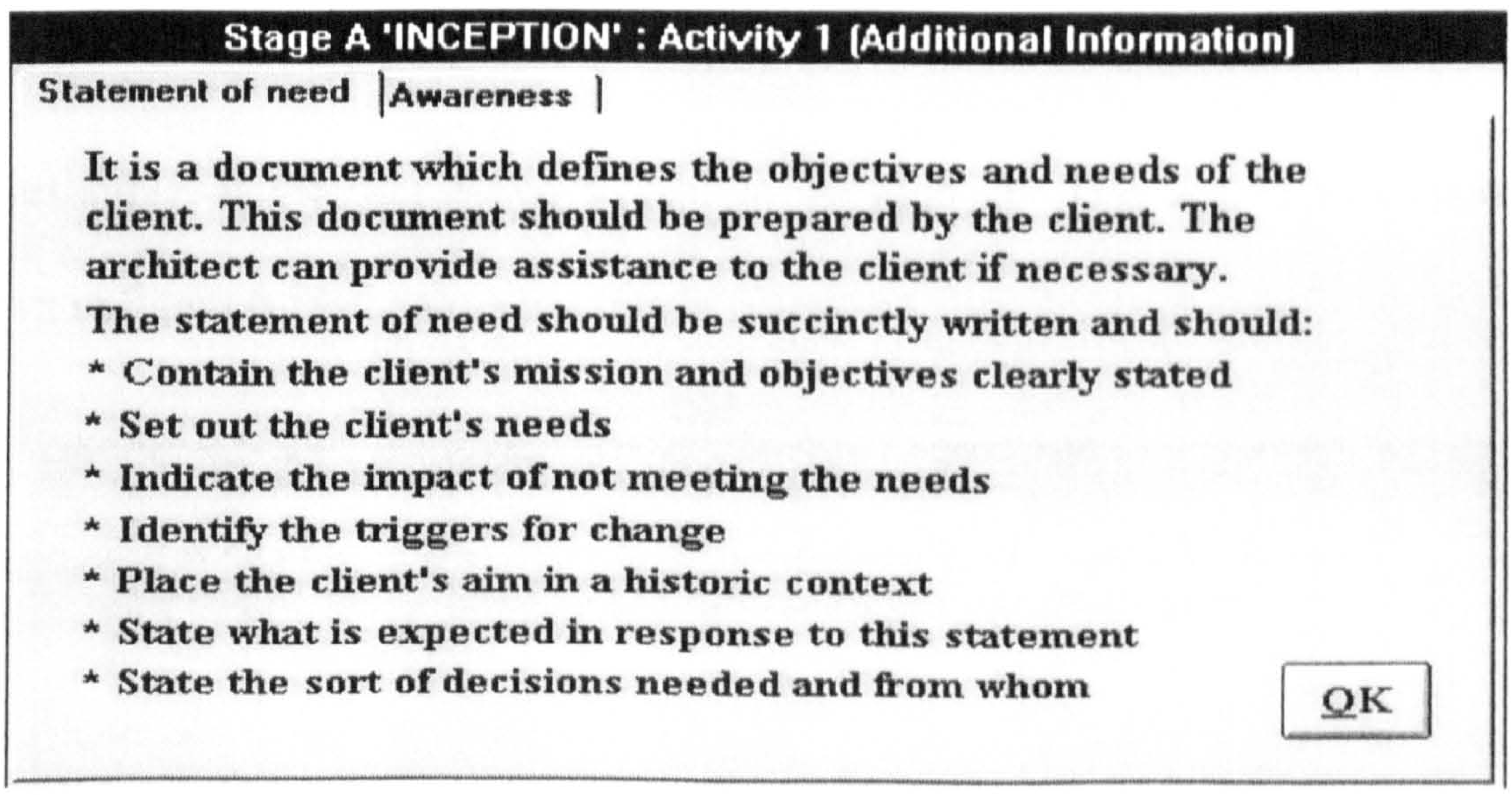


Figure 6.17 Additional information 1 of Activity 1 of Stage A 'Inception'

There are two pages in the 'Additional Information' screen. Apart from the information, the page of awareness is also included as this activity is the 'hotspot' activity (see figure 6.18).

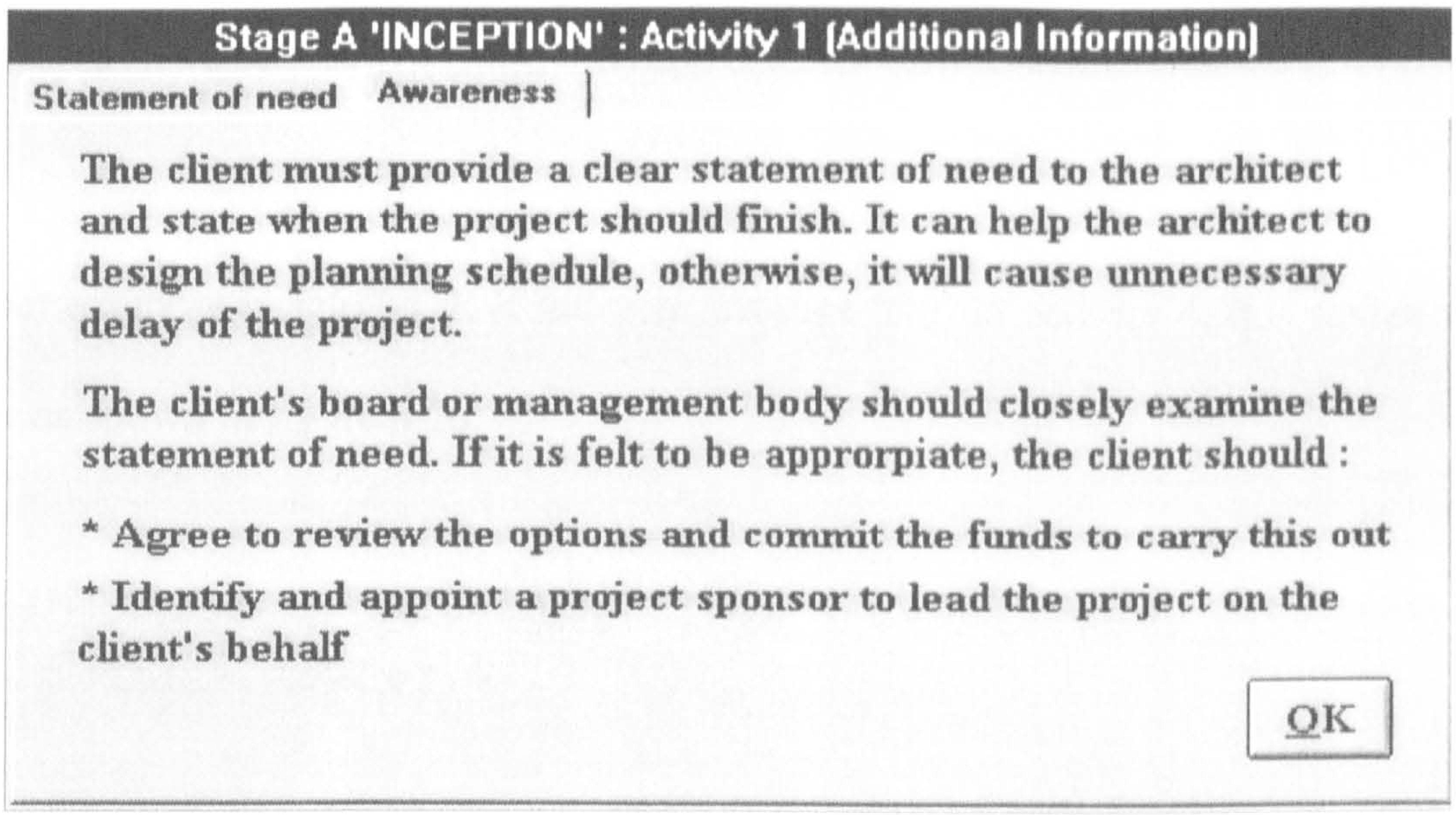


Figure 6.18 Additional information 2 of Activity 1 of Stage A 'Inception'

This is the basic operation of CONBPS. There is some exceptions on certain 'hotspot' activities.

For example, if the user answers 'No' to question 2b. This screen will appear as shown in figure 6.19.

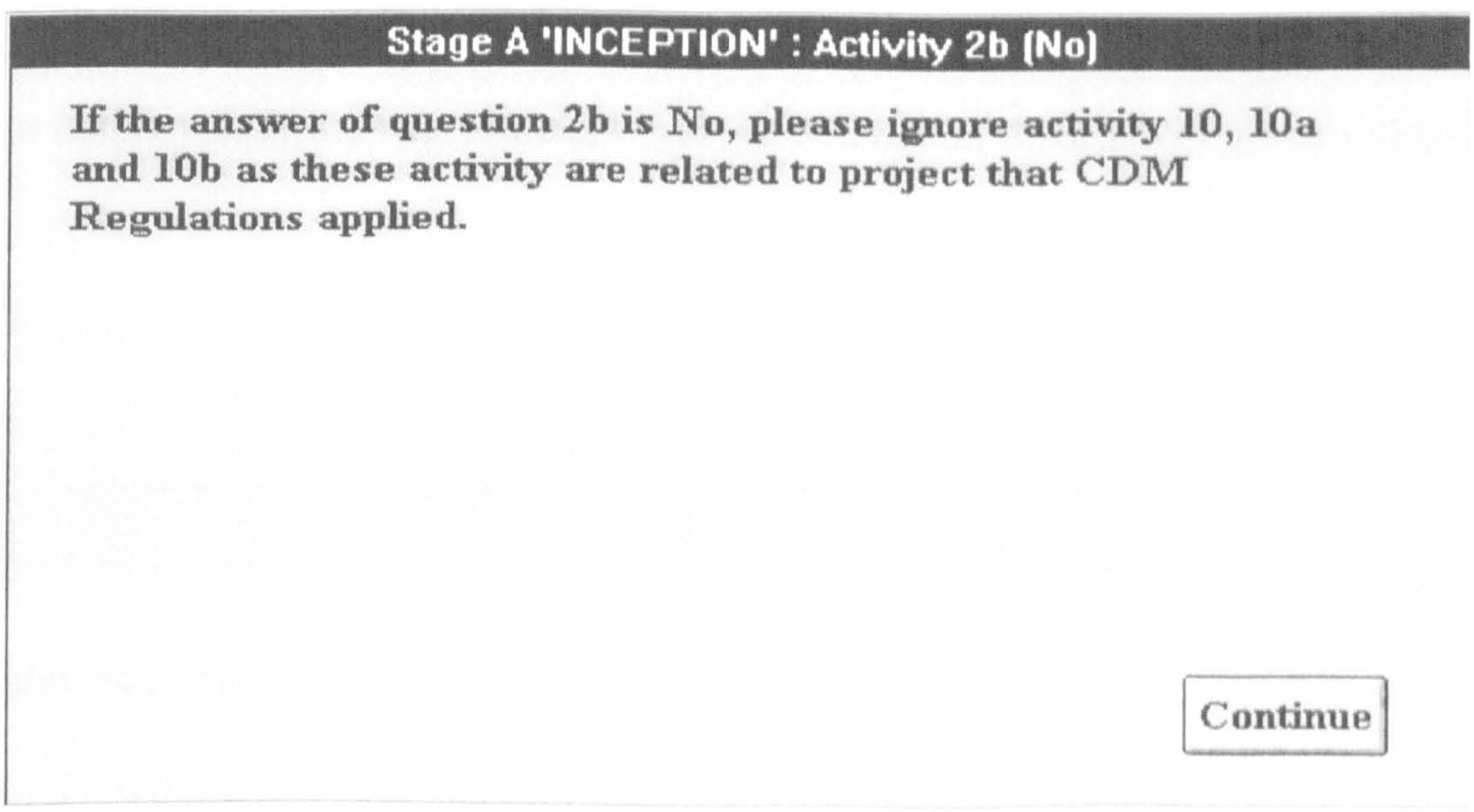


Figure 6.19 Screen that shown if answer 'no' to Activity 2b of Stage A 'Inception'

The system will save the user's answer and questions 10, 10a and 10b will not be asked, as these are irrelevant to this user.

Another example is activity 4. If the user answers 'No' to activity 4, this screen will appear as shown in figure 6.20.

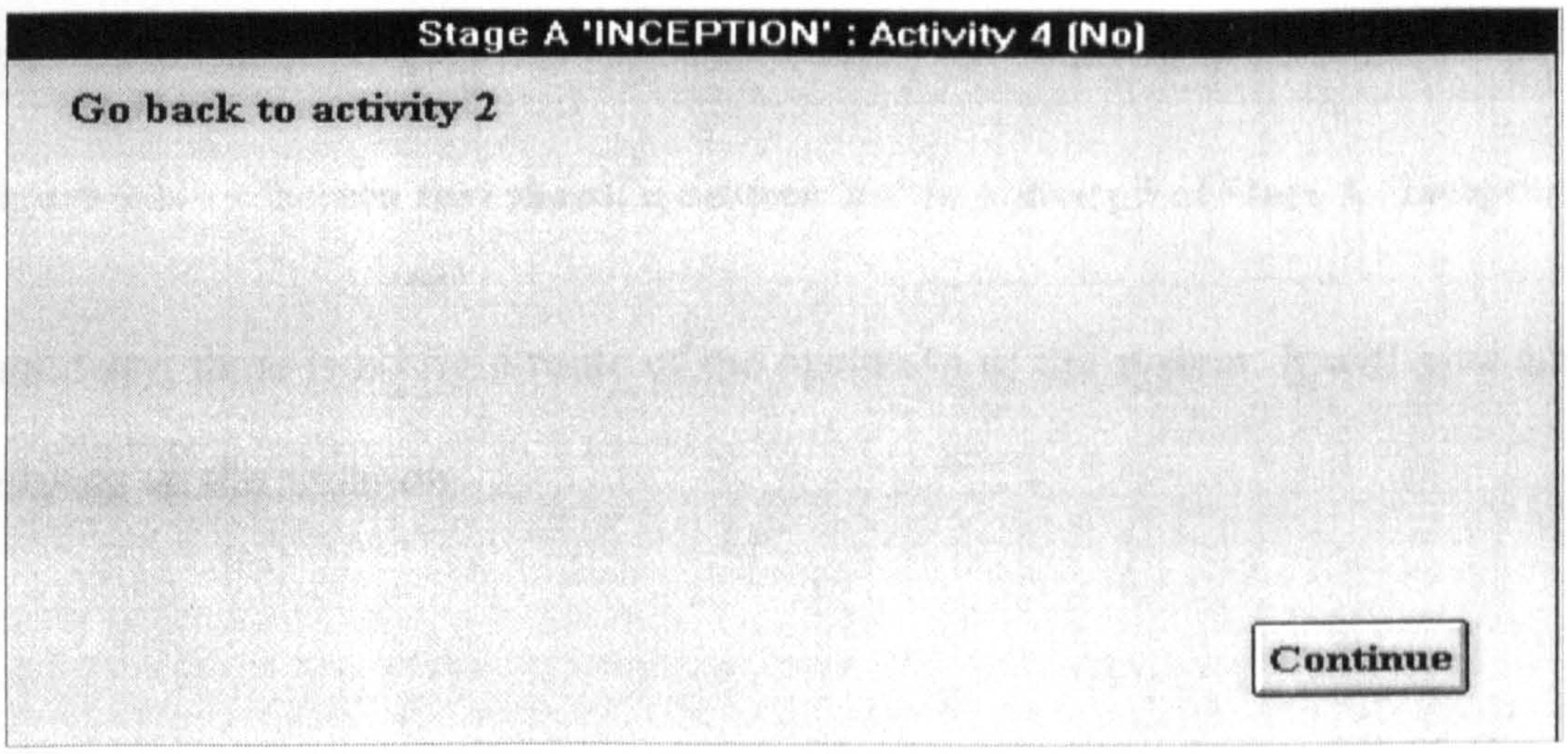


Figure 6.20 Screen that shown if answer 'no' to Activity 4 of Stage A 'Inception'

Activity 4 is a critical activity. If the user cannot finish this activity, they should go back as indicated and re-run the procedure again. The system will automatically loop back to activity 2. If the user answers 'yes' in activity 2, then it will go straightaway to activity 4. The user does not need to answer the activity in between activity 2 and 4 again.

The third example is activity 5. It is also a 'hotspot'. Instead of a loop back to a particular activity, the system will give advice. If the answer 'No' to this activity, figure 6.21 will appear. The user presses 'continue' in this screen and it will continue to the next activity.

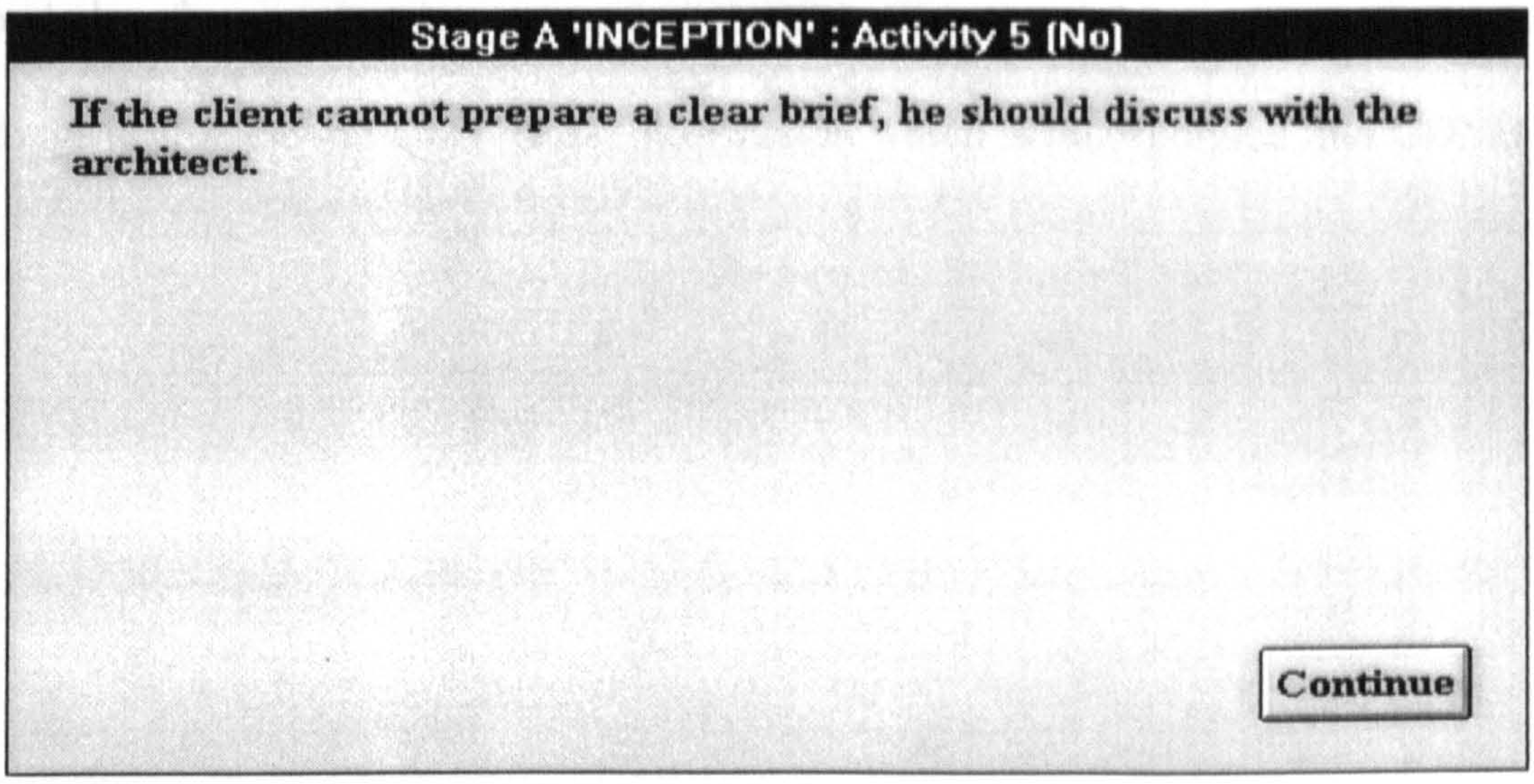


Figure 6.21 Screen that shown if answer 'no' to Activity 5 of Stage A 'Inception'

In summary, there is no rigid route of the operation of the system. It will give advice depending on the situation.

6.8 Reflection and conclusion

This chapter has reviewed the development of the prototype version of CONBPS. Firstly, it stated the background information of an expert system, including the discussion of its definition, description, structure as well as its suitability and application in the construction industry. The development of CONBPS followed including identification of its development tool, discussion of its knowledge acquisition process, its knowledge representation and its operation process.

One of the critical issues of the development of an expert system is the knowledge acquisition process and it is further discussed in chapters seven and eight. Chapter seven discusses the research methodology of this project. It is the process of acquiring knowledge for the development of CONBPS. Chapter eight discusses the research findings of this project and it is the information which is incorporated into CONBPS.

Chapter 7

Research methodology

7.1 Introduction

The research can be considered to be qualitative in nature. The overall methodology adopted can be classified into steps as follows:

Stage one: Desk-based study of research reports and relevant literature on the research subject.

Stage two: Conducting a pilot study.

Stage three: Development of the prototype CONBPS. The source of information is from the literature review and the pilot study.

Stage four: Interviews with various construction participants.

Stage five: Analysis of the findings from the interviews and incorporating them into the system.

Stage six: Development of an updated system.

Stage seven: Validation of CONBPS.

Stage eight: Verification of CONBPS.

Stage nine: Development of a finalised CONBPS based on the comments from the evaluation stage.

The development process and the outcome of stage one and stage three have been discussed in chapters five and six respectively. Stage five to stage nine are discussed in chapters nine and ten.

The aim of this chapter is to discuss the process of obtaining data in stage two and stage four. The research findings are reported in chapter eight.

7.2 Pilot study

7.2.1 Description of targeted respondent

In order to avoid the problem of biases of the respondents, one discrete sector of the construction industry was chosen for investigating. The chosen target should have substantial experience in property development, be familiar with construction procedures and preferably neither private nor public developer. This is because both private and public developers will have their own preference for construction procedure and practice.

The chosen targeted respondents are the Housing Associations within the West Midlands area of England. Housing Associations are the non-profit making societies or companies established for the purpose of providing accommodation which will be let to tenants. Besides, the Housing Associations are a dominant provider of new social housing. In 1998/ 99, their expected development in the UK was worth around £2 billion and the total production was expected to be around 30,000 homes per annum (Egan, 1998).

The West Midlands is a geographically diverse region. The decline in the manufacturing sector has had a severe impact in the region, which led to a rapid increase in unemployment and below average wages for those in work. The West Midlands now ranks second after Northern Ireland for long-term unemployment rates and has the highest infant mortality rate in the UK. Because of its specific historical background, the Housing Associations in this region should have more opportunity to build various types of accommodation. In other words, their experience on construction projects should be high (NFHA, 1996).

7.2.2 First stage pilot study

The process for collecting data was divided into two stages. The first stage was to distribute the letter requesting for co-operation. The addresses of the Housing Associations were abstracted from the Housing Association's Directory and Yearbook (NFHA, 1996).

At the beginning, sixty letters were sent to Housing Associations in the West Midlands area. As the respondent rate was not sufficient, another ninety-one letters were sent to the rest of Housing Associations in the West Midlands.

The purpose of sending this letter was to identify which procurement method and conditions of contract they used. The letter contained the four questions listed below:

- Does the association usually use traditional design services for construction projects?
- Does the association usually use the Joint Contracts Tribunal (JCT) 80 as the standard form of construction contract?
- Does the association employ an independent safety manager for construction projects?
- Are you willing to co-operate in completing a short questionnaire?

The respondents were required to choose either 'yes' or 'no' to the above four questions.

The original information that was sent to the Housing Associations is shown in appendix four.

Eighty-one respondents responded and five letters were returned because of an incorrect delivery. The response rate was 54%. Thirty-three respondents answered 'yes' to question one, thirty-two answered 'yes' to question two, forty-three answered 'yes' to question three while forty-six answered 'yes' to question four. The reasons for the respondents not willing to fill the questionnaires included:

- No knowledge of development, some of them answered that they act as agent
- Limited development knowledge
- Responsible only for welfare of residents in the district

- Housing Association had been closed

Although there were forty-six respondents willing to complete the questionnaire, some of them were not using the traditional procurement strategy or the JCT 80. Finally, only twenty respondents were selected for further co-operation.

7.2.3 Second stage pilot study

As the framework of the twelve construction stages (from inception to feedback) as identified in the RIBA Plan of Work, needed to be sent out, it was considered excessive to send all twelve stages to each Housing Association. Therefore, the twenty respondents were divided into four groups, each group was sent three-construction stages for comment.

A standard letter briefly explaining the survey along with the framework was sent to the respondents. Besides, several questions were asked. The questions were divided into two parts. Part A questions focused on comments within the diagram and Part B asked about the speciality of the respondents. The reason for asking Part B questions was to ensure the respondents had enough knowledge and experience for commenting on the framework.

The questions are listed below:

Part A

1. Are the critical issues describing each activity appropriate?
2. Are the project team members responsible for each activity appropriate?

3. Is the sequence of work in the right order?
4. Is the description of each activity clear?
5. Have some activities been omitted?
6. Do you have any additional comment?

Part B

1. With which procurement strategy are you most familiar, e.g. Traditional, Design and Build etc.?
2. Which standard form of contract do you use, e.g. JCT 80 with quantities?

The original information that was sent to representatives in the Housing Associations is attached in appendix five. It includes a cover letter, a reply form, and a note describing the diagrams and a set of diagrams. Each respondent received the theoretical framework for the twelve construction stages.

The frameworks have been updated after receiving the comments from the representatives and the updated version is shown in appendix two. The updated theoretical framework is the information that was later sent to construction participants who were involved in the major survey.

Following telephone calls, twelve questionnaires were received in the second stage of the pilot study, but two of them refused to comment on the framework. The distribution pattern of returned questions is shown in table 7.1 and the reference number of the respondents is identified in the same table. The status of respondents is shown in table 7.2.

Table 7.1 Response from second stage pilot study - Housing Association

Groups of Housing Association	Number of respondents	Reference number
1 (comment on Stage A to C)	2	Respondent 1 and 2
2 (comment on Stage D to F)	5, but 1 refuse to comment	Respondent 3, 4, 5 and 6
3 (comment on Stage G to J, no Stage I)	3	Respondent 7, 8 and 9
4 (comment on Stage K to M)	2, but 1 refuse to comment	Respondent 10

Stage A: Inception, Stage B: Feasibility, Stage C: Outline Proposals, Stage D: Scheme Design, Stage E: Detail Design, Stage F: Production Information, Stage G: Bills of Quantities, Stage H: Tender Action, Stage J: Project Planning, Stage K: Operation on Site, Stage L: Completion, Stage M: Feedback

Table 7.2 Position of respondents

Position of respondent	Number
Director	1
Chief executive	1
Development manager	2
Director of property	1
Development officer	2
Development co-ordinator	1
Senior surveyor	1
Technical officer	1

All respondents were familiar with the traditional procurement strategy and the JCT 80 condition of contract (with quantities). They were also familiar with:

- Design and Build (procurement strategy)
- JCT 81 with contractor design
- JCT with minor work
- Design and Build with quantities
- ASI minor work contracts

As all of them were familiar with the traditional procurement strategy and the JCT 80, their comments were considered reliable.

Based on the literature review and the comments from the representatives of the Housing Associations, the prototype of CONstruction Best Practice System (CONBPS) was developed.

7.3 Major survey

The methodology used for collecting the practitioners' opinion was by interview. The targeted respondents are all participants who were identified in the prototype CONBPS. As the aim of CONBPS is to identify the responsibilities of various participants in the construction project, it should therefore include the opinions from all the parties to have a comprehensive picture.

These respondents included architects, quantity surveyors, planning supervisors and clients (private and public client). In addition, representatives of the Housing Associations who participated in the previous stage of the research were also interviewed. As only the first four stages of the RIBA Plan of Work have been developed, contractors were not included and were not interviewed.

The companies and professional practices were selected from the following sources:

- Architect - Architect's Directory of Practices (RIBA, 1998)
- Public Client - Municipal year Book 1999 and Public Service Directory. Volume 1: Function and Offices (Lauren, 1999)
- Private Client – Estate Gazettes Directory (Estate Gazette, 1999)
- Quantity Surveyor - Top 250 Consultants (Cavill and Osbourne, 1999)

- Planning Supervisor – Name list from Association of Planning Supervisors (APS)

In addition, the Housing Associations that have participated in the pilot study were chosen for interview.

A standard letter briefly explaining the survey along with explanatory information on the CONBPS framework was sent to the respondents. Additionally, several questions were also asked. These questions were the same as the questions which were asked in Part A of the second stage pilot survey.

The original information sent to the construction participants is listed in appendix six. It includes a covering letter, a reply form, a note for description and two sets of information.

There are two sets of covering letters and reply forms which are targeted at new construction participants and Housing Associations' representatives respectively.

The first set of information identifies the theoretical framework of the construction process and is shown in appendix two. The second set of information was the screen of the file 'Intro' of the updated CONBPS and it is shown in appendix eight.

The initial letters were later followed up by a telephone call. Finally, 33 respondents replied, but 10 refused to have an interview. The reasons for the respondents not willing to be interviewed included:

- Very busy
- Do not have experience in this area
- Targeted person has left the company

The distribution pattern of returned questions is shown in table 7.3. The status of respondents is shown in table 7.4.

Table 7.3 Responding pattern of major survey

Parties	Send out	Reply	Willing to participate	Percent
QS	10	5	5	50
Architect	15	7	4 interviewed, 1 post comment	33
Planning Supervisor	10	6	4 interviewed, 1 post comment	50
Public Client	12	7	2 interviewed, 1 post comment	25
Private Client	10	4	2 interviewed	20
Housing Association	10	4	2 interviewed, 1 post comment	30
Total	67	33	23	34

Table 7.4 Position of respondents

Position of respondent	Number
Director	7
Chairman	1
Managing Director	1
Chief Executive	1
Department Head	1
Development Manager	1
Director of Development Services	1
Associate Partner	2
Area Manager	1
Construction Manager	1
Project Manager	1
Section Leader	1
Quality System Officer	1
Planning Supervisor	1
Quantity Surveyor	1
Architectural Technician	1

The interviews were conducted at the interviewees' own offices and were conducted within the context of semi-structured interviews. Timescale of interviews ranged from thirty minutes to two hours. All interviews were tape-recorded and transcribed verbatim. The interviews were undertaken over a period from November 1999 to February 2000. Together with all informal discussions the interviews gave a comprehensive review of the new process model.

Before the interview started, some background information of the interviewee was requested. These questions included asking about the experience of the interviewees and their experience of the traditional procurement strategy. The reasons for asking these questions were to ensure the interviewees had enough experience in order to comment on the system. The description of their experience is stated in table 7.5.

Table 7.5 Experience of interviewees

Respondent	Experience	Experience on traditional procurement strategy
QS-1	Early experience is quantity surveyor. Later worked as project manager.	Work as QS since 1984. Familiar with JCT contract.
QS-2	Fellow of RICS. An Associate in this company for the last ten years. Before, he was an associate project manager.	Did quite a lot for work using traditional procurement strategy, but the last one that he did was in 1995.
QS-3	Graduated in 1993 and finished APC in 1995. Five years working experience in quantity surveying work.	Some experience on traditional procurement strategy.
QS-4	Background is QS and worked for 25 years. Focus on developing information technology issues in the past 20 years.	25 years

Respondent	Experience	Experience on traditional procurement strategy
QS-5	Worked as a chartered quantity surveyor for 14 years.	Basically, the whole of his career is related to projects which use traditional procurement strategy.
Arch-1	Early experience is architect. Worked as project manager in the past 15 years.	70-80% of 15 years experience using traditional procurement strategy.
Arch-2	35 years experience as an architect, 30 years as principal of company. He has run his own business for 20 years. Now works as project manager.	35 years
Arch-3	He is an interior designer and architect and has 30 years experience. Currently is the principal and senior partner of the company. Apart from practical experience, he also taught in the university in UK and HK.	Almost total 30 years experience in traditional procurement strategy. Although he was also involved in design and build, but traditional procurement strategy is but still dominant.
Arch-4	Worked as an architect since 1980, and qualified in 1985. Has wide experience on different kinds of construction projects.	Since 1980
Arch-write	Director	
PS-1	Worked as an architect for 25 years and member of Association of Planning Supervisors. Worked as Planning Supervisor in recent years.	25 years
PS-2	26 years experience in construction. Work at all levels from site engineer to director. Besides, he also worked as part-time lecturer in university. Member of Association of Planning Supervisors, Institute of Builders, and Chartered Architect.	26 years

Respondent	Experience	Experience on traditional procurement strategy
PS-3	Qualified quantity surveyor qualified for 40 years and member of Association of Planning Supervisors.	40 years
PS-4	Worked an as architect for 28 years. Since 1995, worked as full time Planning Supervisor.	Most of the experience is in traditional procurement strategy when working as an architect. Besides, he was also in involved in other procurement strategy, like Design and Build.
PS-write	Architectural Technician	
Pub-Cl-1	Currently is the Head of Building Services. Previously, he was company area manager and property services manager.	Most of his experience is in traditional procurement strategy.
Pub-Cl-2	Qualified quantity surveyor for 20 years.	All of his experience is traditional procurement strategy.
Pub-Cl-write	Director of Development Service	
Priv-Cl-1	Background quantity surveyor. In 1989, he started to participate in the project management. He has been a project manager since 1998.	30-40% of his experience is working on traditional procurement strategy.
Priv-Cl-2	Early experience is architect. Worked as construction manager for the past 14 years.	Most of his experience is in traditional procurement strategy.
HA-1	20 years experience in construction-related work.	Has a lot experience on traditional procurement strategy. However, he did not work on this procurement strategy in last five years.
HA-2	35 years experience. He was a contractor for Housing Association developments.	35 years
HA-write	Area Manager	

After asking the backgrounds of the interviewees, the computerised system was demonstrated. The author explained the operation of the system and the rationale for designing the system. After doing the demonstration, the author asked the interviewees to comment on the following points:

- Were the critical issues describing each activity appropriate?
- Were the project team members responsible for each activity appropriate?
- Was the sequence of work in the right order?
- Was the description of each activity clear?
- Had some activities been omitted?

Basically, the questions were the same as in the reply form. Additionally, comments were also sought on the interface of the system together with any relevant additional comments.

The purpose of the interviews was to confirm or modify the model so as to ensure the roles and responsibilities of all parties and the sequence of the activities were accurately represented.

7.4 Reflection and conclusion

This chapter has discussed the research methodology of this project. It is basically divided into two stages. The first stage aimed at seeking comments on the developed theoretical framework. It was proceeded by sending the developed theoretical framework to a discrete construction sector, i.e. Housing Associations for their comments. The second stage sought comments from the identified participants on the prototype CONBPS. The method used to collect their opinions was through the use of interviews which included a demonstration of the proposed system. The findings of these surveys are discussed in chapter eight in detail.

Chapter 8

Research findings

8.1 Introduction

This chapter aims at discussing the research findings. It is divided into three sections. The first section focuses on the findings from the pilot study, the second section is the overall research findings of the major survey while the last section is the review of practitioners' comments on CONBPS.

8.2 Research findings of the pilot study

Generally speaking, all respondents agreed on the design of the framework and the sequence of the activities. They did not have critical opinions on the six questions that were listed in Part A.

Some respondents, especially the respondents who were in the top managerial level had more comments on the framework. It may be due to the fact that they have more experience on the full development process. Although they were asked to comment on different construction stages, some of their comments are similar and they are grouped under the following areas.

8.2.1 Increased involvement of the client

Both Respondent 1 and Respondent 3 commented that clients should have a greater involvement in the pre-contract stages.

Respondent 1 emphasised that the client should state their requirements clearly at the beginning. Besides, he mentioned that the client must tackle the following issues in Stage A – 'Inception':

- Review company policy
- Undertake market research/ social research
- Consider customer expectations
- Consider accessibility of site location
- Consider political or social constraints/ pressures
- Undertake revenue projections and outline capital budget
- Draw up development programme
- Carry out development risk analysis
- Decide procurement route
- Draw up brief for consultants

He further emphasised that 'failure by a client to address any or all of these issues could result in an inadequate brief and could lead to detrimental and costly changes of mind to the design later on'.

Respondent 3 also stated that the client should be involved more in Stage F (Bills of Quantities), stating that the client should prepare the list of tenderers. Besides, he also stated that the client should have a more active role in project discussion and making the final decision.

Their comments are in the same direction as a lot of research on construction management, e.g. NEDO (1975) and recent publications like Latham (1994) and

Potter (1995) etc. All of their comments are that 'increased client involvement will increase the chance of success'.

8.2.2 Increased involvement of the planning supervisor

Respondent 4 stated that the planning supervisor needs to be involved more during Stage D (Scheme Design). He considered that the planning supervisor needs to see the sketch scheme prior to the final design and the Bills of Quantities being prepared. Both the client and the planning supervisor need to be involved with preparation of the tender list.

Respondent 4 is employed as a technical officer, and this may be the reason that he was aware of the specific issue.

8.2.3 Procurement process for private sector is easier

Respondent 3 stated that the procurement within the private sector is far easier than within the public sector. He mentioned the following reasons:

- Public sector rarely uses standard house types due to regional government restraints
- Many individuals play major or minor parts in the development process within the public sector, whereas the private sector tends to have fewer players
- The public sector has many clients/ end users to consider, e.g.:

    - Local Authority
    - Housing Corporations
    - Tenants
    - Resident Groups
- The private sector property sales often offer little or no choice as to what's on offer for the consumer

His opinion is in the same direction as the reason why the author chose Housing Associations as the targeted respondent.

8.3 Research findings of the major survey

The respondents' comments can be classified into two aspects; firstly to comment on each activity, and secondly to comment on the overall system. As the detailed comments on the activities were piecemeal, they will not be reported in this section, instead they will be included in the amendment of the system only.

The research findings that will be discussed in this section are focused on the comments on the overall system. The following sections report the comments in the same order as questioned by the author.

8.3.1 Criteria

Some respondents commented that the definition of the criteria should be stated more clearly. They pointed out two aspects. Firstly, the meaning of the criteria, which is especially important for the 'hotspot'. Time, cost, quality and safety are the common criteria for defining the performance of projects. Although the definitions are not stated clearly, it is still easy for the participants to understand the meaning. However, 'hotspot' is not a common term. Therefore, it is necessary to define it more clearly. Secondly, the level of the criteria; for example, if the criteria of a certain activity is time, the weighting should be made clear in absolute or percentage terms.

Besides, one respondent mentioned that 'client satisfaction' should be one of the criteria. After reflection, it was considered that client satisfaction is a subjective issue and it should not be measured until the project is finished, it should not be included in the framework.

8.3.2 Roles of the parties

The first comment is that certain roles should be added. These roles include consultant engineers, project managers and specialists such as environmental specialists etc. The respondents commented that consultant engineers have an important role in the construction process, sometimes they are responsible for 40-50% of the cost of the construction project. Therefore, it is tremendously important to incorporate their roles in the framework. Besides, the role of project manager should also be included. This is different from that stated in the RIBA Plan of Work. According to the RIBA Plan of Work, it is not necessary to appoint a separate project manager as traditionally the architect undertakes the dual role acting as designer and project leader.

The second aspect is that certain roles should be explained more clearly. The role of quantity surveyor is very clear. However, it is advisable to define the role of the client, the planning supervisor and the architect more clearly. For the client, it is important to explain whether they are purely the sponsors or whether they participate directly in the construction process. For the architects, it is more advisable to define whether they are responsible for design only or responsible for management as well. The respondents suggested that it would be advisable to divide their roles as it is the common practice nowadays. For example, the modern trend is that the architect is responsible for design only.

The respondents commented that there is too much emphasis on the role of the planning supervisor at the early construction stage. According to their practical experience, the planning supervisor will not participate so much in the early construction stages. This is in contrast with the comments from the Housing Associations in the pilot study.

Finally, the respondents mentioned that it is not necessary to appoint the architect as the first consultant. As the pre-determined criteria for the feasibility of the project is budget, therefore, it is usual to appoint the quantity surveyor first. Besides, the quantity surveyors usually act as the leader of project team nowadays. Again it is in contrast to what has been stated in the RIBA Plan of Work.

8.3.3 Sequence of work

The RIBA Plan of Work considers the building cycle as a sequential process, therefore, the design of CONBPS also follows this design. The respondents stated that it is not applicable to the real world. Time is the most important element in the construction project, therefore, it is usual for the stages to proceed in parallel. The design of the construction activities in sequence is applicable theoretically, but it is difficult to apply to a real world project.

8.3.4 Description of activities

All respondents found that the description of activities were clear. However, they pointed out that it may be difficult for the inexperienced clients or users to fully comprehend the text. The interviewed respondents were experienced participants, therefore, they did not have any difficulties in understanding the construction jargon and terminology. Although there is further explanation in the information section, it may not be enough for inexperienced clients.

Moreover, the respondents commented that certain activities, like cost advice, risk management and value management should be bought in at an earlier stage. These activities are 'continuous activities'; they are not one-off, therefore, they should be considered within the different stages in the process.

Additionally, respondents advised on grouping the activities into headings. For example, cost management is one big heading. Under this heading, there are the sub-headings like cost control, cost advice and cost estimates etc. Because not all activities have the same level of importance, it is therefore necessary to classify them in a hierarchy.

8.3.5 Omitted activities

All the respondents generally agree that there are no omitted activities. However, they also pointed out that it depended on which level the activities have been classified. Some respondents' companies also prepare this kind of plan. The numbers of activities in their plan is around 600, which is much more than the activities in the CONBPS system. As the purpose of CONBPS is for use as a guidance or manual for the construction process, it has identified only the key activities. Besides, it is not designed to apply for one particular company or project. If it is too detailed or includes too many activities, it will decrease its general usability.

8.3.6 Interface

All the respondents agree that the design of the system is user-friendly and easy to follow. They appreciated the function of providing additional information. Moreover, they welcomed the use of the symbols to represent the critical criteria. They also advised that certain functions should be added in the system including:

- The function of 'jump to' a specific activity
- The function of recording the answer that the previous users had responded
- The function of going back to the previous activity if the users choose the wrong icon
- Add the reminder list indicating what the client should do in the short term

The reason for adding these functions is because it is impossible in the real world to finish the project in a short time-scale. The projects are usually divided into a large number of activities completed over a very long time-span. Therefore, it is a good idea to add these functions so as to help the user.

8.3.7 Additional comments

Apart from the comments under each heading, the respondents also gave some additional comments on the overall system.

The framework had been sent to the users before the interview. They mentioned that the first impression of the flowchart is that it is very complicated as there are excessive activities compacted on one page. However, the presentation of the system via the computer is easier to understand. Each activity is shown on one screen and the current activity has been stated as well. The participants considered that the criteria had been identified clearly and were easy for the user to understand.

The respondents also commented that the system seems tailored to big projects as it is very detailed and includes many activities. It is not common for a small-scale project to contain so many activities.

The final comment on the system included the recommendation to keep the text as simple as possible. Basically, the users preferred to see simple rather than complex text. This is in contrast to the author's approach as the author thought it necessary to make the system as detailed as possible.

8.4 Comparison of practitioners comments on CONBPS

8.4.1 Criteria

All representatives of the planning supervisors agreed on the criteria that had been identified. All other parties however had additional comments, e g.:

The architects commented on the definition of the criteria especially the term 'hotspot'. It was easier for them to understand criteria like time, cost and quality as these are the traditional determinants. However, 'hotspot' is not a common term, therefore, it was necessary to define it more clearly.

Quantity surveyors were more focused on the level of the criteria. One example they mentioned was that, if the criteria of a certain activity was 'time', the weighting should be made clear in absolute or percentage terms. Besides, they also suggested 'client satisfaction' should be added as criteria. As client satisfaction is a subjective issue and cannot be measured until the project is finished, it will not therefore be included in the framework.

One representative from the Housing Associations mentioned that there is often a difference in criteria for different clients. For example, the private client is more focused on time, while the public client is probably more focused on cost.

8.4.2 Roles of the parties

All professionals, who included quantity surveyors, planning supervisors and architects, suggested that certain roles should be added. The discussion on adding new roles has been discussed in section 7.3.2, therefore, it will not be repeated in this section.

On the other hand, clients mentioned that their own role should be explained more clearly. They mentioned that 'it is important to explain whether they are purely the sponsors or whether they participate in the construction process'. The role of leading clients has changed tremendously in recent years and is widely different in various projects (Potter, 1995). Experienced clients, like British Airway Authority (BAA), actively participate in the management of building projects. On the other hand, a small company, acting as a client will take a more traditional role.

The third comment from the respondents is that the architect is no longer the leader of the construction team. Quantity surveyors explicitly expressed the opinion that 'quantity surveyors are the team leaders nowadays'. Besides, the representatives from Housing Associations, planning supervisor and architects also mentioned that it is common practice to employ the quantity surveyor as the first consultant in building projects. The quantity surveyor is responsible for preparing cost advice and the cost plan; cost being the most critical pre-determinant of the feasibility of a project. The planning supervisors also commented on the modern role of the architect, stating that 'architects are responsible for design only'.

The planning supervisors also commented that their involvement in the construction usually commences later, often at the construction stage. This is in contrast with the comments from the Housing Associations in the previous survey.

8.4.3 Sequence of work

Planning supervisors, quantity surveyors and clients did not agree that the RIBA Plan of Work in a sequential process fully reflects the construction process. The detailed discussion has already been mentioned in section 8.3.3.

8.4.4 Description of activities

Fundamentally, all respondents could understand the description of the activities. Only one quantity surveyor mentioned that it might be difficult for the inexperienced clients or users to fully comprehend the text. Although there is further explanation in the information section, it may not be enough for inexperienced clients.

8.4.5 Omitted activities

All respondents agreed and could not find any omitted activities.

8.4.6 Interface

All respondents agreed that the design of the system was user-friendly and easy to follow. They appreciated the function of providing additional information. Moreover, they welcomed the use of the symbols to represent the critical criteria.

However, the quantity surveyors were more focused on the 'recording' function of the system. They suggested adding the function of recording the answer that the previous users had given and adding a reminder list indicating what the client should do in the short term. On the other hand, planning supervisors and architects were more focused on the 'design of the icons'. They suggested introducing icons which 'jumped to' a specific activity should be added together with a facility to allow users to go back to the previous activity if the wrong icon was chosen.

8.5 Reflection and conclusion

Basically, all the respondents at the pilot and major surveys agree with the development principles of CONBPS and welcome the design of the system.

At the pilot stage, the received comments were limited. This was probably due to the limited information that the respondents received.

During the major survey, there were more comments and the comments varied among different kinds of respondents.

Clients had the fewest comments, which may be due to the fact that the targeted respondents did not have much experience of construction. Clients advised that the role of client should be clearly defined, acting either as a pure sponsor or should actively participating in the construction project. This reflected the dilemma of the changing role of the client in the construction project. This could be seen as one of the reasons for the conflict within the construction project, as the identification of the client's role by themselves is different from the opinion of the professionals.

All respondents agree that the architect is no longer the leader in the construction team. The architect acts solely as a design manager and an independent project manager is responsible for administration and co-ordinating issues.

Both quantity surveyors, planning supervisors and clients mentioned that the construction process is not sequential, as time is the most important element in the modern world; this is in conflict with the RIBA Plan of Work. On the other hand, the architects still consider that the RIBA Plan of Work is a useful guide for a construction project.

The perception of the role of planning supervisor also differed. Planning supervisors mentioned that they would not be involved until the construction stage. On the other hand, the respondents from the Housing Associations in the previous survey had the opposite opinion. This is another example, which reflects the difference in understanding the roles of the parties.

Apart from the general comments on the construction project issues, there are also some different comments which focus on the design of CONBPS. For example, architects focused on the definition of the criteria while the quantity surveyors focused on the level of the criteria.

According to the findings of this survey, it has been discovered that different construction parties have different opinions of the construction process. Besides, the understanding of each other's roles is often ambiguous. It supports the argument of the literature review that 'the divergent background and specialist skills of the project team members is the ultimate justification for the under-achievement of construction project'. The development of the expert system CONBPS will lead to a better understanding of the role of the parties and the activities required to be performed.

Chapter 9

Development of updated CONBPS

9.1 Introduction

There is no systematic overall methodological procedure for incrementally extending and reviewing knowledge bases. Jackson (1999) has stated that 'there are no well-understood or widely accepted methodology for incrementally extending knowledge bases in the manner of review' (p.191). Shaw and Woodward (1993) also stated a similar opinion in a more explicit way. They mentioned that 'there is, at present, no systematic overall methodological framework for knowledge acquisition to guide the organisation and arrangement of the appropriate application of the many manual and automated techniques and methods used for knowledge acquisition' (p.78).

Therefore, the methodology for incorporating the practitioners' comments on CONBPS is developed on a 'tailor-made' basis, i.e. specifically for this project.

The method for collecting practitioners' comments has been discussed in section 7.3 and the research findings in sections 8.3 and 8.4. As the data is collected by an interview and the author transcribes the information, it is more focused on the qualitative nature.

9.2 Conditions of use for CONBPS

Construction projects vary widely and it is impossible to develop a process model which can be applied to all construction projects. CONBPS can be applied to building projects which have the following characteristics:

- Use the traditional procurement strategy
- New building for general purpose
- Not subject to abnormal subsurface condition
- The client has no in-house consultants

9.3 Amended theoretical framework

Before describing the amended theoretical framework, the items that need to be considered following the feedback received from the practitioners will be discussed. These comments will focus on *the criteria*, *the roles of the parties* and *the description of the activities.*

With regard to 'comments on the criteria', these involve giving an additional explanation of the terminology. Therefore a screen with an explanation of the terminology will be added to the introductory screen in the system.

In the 'roles of the participants' section, several roles have been added, which include project manager, structural engineer and service engineer. The project manager is responsible for the management and administration of the project-duties which was traditionally the architect's role. The structural engineer is responsible for issues concerning the structural efficiency and stability. The building services engineers are obliged to design the installation of the internal control systems, i.e. heating, ventilating, air conditioning and lighting installations, and utilities such as electrical supplies, lifts and compressed air.

The roles of the parties will be explained more fully at the commencement of the operation of the CONBPS. Besides, within each activity, the major party and the participants who provide support will also be identified in the framework.

There are also some amendments on the 'description of activities'. In order to make it easier to understand, the text of the activities will be simplified. Besides, some activities, like *value management*, *risk management* and *cost management* will be identified as continuous activities, as they should be undertaken throughout the project. Additionally, the activities will be classified in a hierarchy. Some activities, like cost management have one big heading. Under this heading, there are sub-headings, like cost control, cost advice and cost estimates etc. Not all activities have the same level of importance, therefore it is necessary to classify them in a hierarchy.

Figure 9.1 and 9.2 is the updated theoretical framework.

Stage A: Inception

Criteria		Activities	Note
H	1	Appoint a project manager	
H	2	Prepare statement of need	
H	3	Assisting the client in order to identify the objectives	
T C Q	4	Prepare project execution plan (explain)	CA
T	5	Prepare process execution plan (explain)	CA
H	6	Identify stakeholders' list	
C Q	6a	Negotiate and appoint relevant stakeholders	Sub
C Q	6b	Select the appropriate principal consultants	Sub
C Q	6c	Discuss with consultants about their terms of appointment	Sub
C Q – No ► Go back to activity 6a	6d	Appoint relevant consultants	Sub
C	7	Meet client to discuss their budget and requirements	
Q	8	Inform client about his job responsibilities	
H	9	Obtain the Client's approval of the project execution plan and direct all the project team for implementation	
H	10	Prepare project brief	
T C Q	11	Establish the project scope	
T	12	Communicate to the consultants about the requirements of Client's Brief	
H	13	Assist in site selection	
Q	13a	Undertake site appraisal	Sub
Q	14	Set up targets and monitoring procedure for the project	
Q	14a	Set up monitoring procedure for the progress of design work	Sub
T	14b	Set up monitoring procedure for regulating programme and progress	Sub
Q	14c	Set up monitoring procedure for co-ordination of the consultants	Sub
C	14d	Set up monitoring procedure for cost and financial reward of project	Sub
T	14e	Set up appropriate channels of communication between project team	Sub
Q	14f	Set up monitoring procedures for performance parameters	Sub
T	14g	Set up consultants' reporting and recording procedures	Sub
T	14h	Set up meeting structure	Sub
Q	15	Co-ordinate the activities on all legal agent issues	
C Q	15a	Advise the client on appropriate procedures for dealing with insurance claims	Sub
Q	16	Advise the client on obtaining appropriate specialist input	CA
C	17	Undertake cost studies	
C	18	Investigate and evaluate financial options	CA
Q	19	Discuss with consultants about feasibility of achieving the objectives	
S	20	Determine whether the project falls within the CDM Regulations	
S	20a	Identify appropriate Planning Supervisor	Sub
H – No ► Go back to activity 20a	20b	Appoint Planning Supervisor	Sub
S	20c	Inform the client of their duties under CDM Regulations	Sub
S	20d	Contribute to Health and Safety File and Plan	Sub
Q	21	Update feasibility plan	
T C Q	22	Undertake site investigations	
T	23	Consult with local authority and other statutory authorities	CA
C	24	Provide cost advice relating to local authority and others etc.	
Q	25	Evaluate structural implications of options	
Q	26	Evaluate services implications of options	
Q	27	Evaluate the feasibility plans	
H	28	Feasibility studies for options and make recommendations	

Figure 9.1 Activities in construction Stage A - 'Inception'

Stage A: Inception

Project Manager	Architect	Quantity Surveyor	Structural Engineer	Service Engineer	Planning Supervisor	Client
1A						1M
2A						2M
3M						3A
4M						4A
5M						5A
6M						6A
6aM						6aA
6bA	6bA	6bA	6bA	6bA		6bM
6cA	6cA	6cA	6cA	6cA		6cM
6dA	6dA	6dA	6dA	6dA		6dM
7M		7A				7A
8M						8A
9M	9A					
10M	10A					10A
11M	11A					11A
12M	12A	12A	12A	12A		
13M	13A					13A
13aM	13aA		13aA			
14M	14A	14A	14A	14A		
14aM	14aA					
14bM						14bA
14cM	14cA	14cA	14cA	14cA		
14dM		14dA				
14eM	14eA	14eA	14eA	14eA		
14fM	14fA	14fA	14fA	14fA		
14gM	14gA	14gA	14gA	14gA		
14hM	14hA	14hA	14hA	14hA		
15M						15A
15aM						15aA
16M						16A
		17M				
18M	18A	18A	18A	18A		
19M	19A	19A	19A	19A		
20M						
20aM						20aA
20bA					20bA	20bM
20cA					20cM	20cA
	20dA	20dA	20dA	20dA	20dM	
21M	21A					
22M	22A		22A			
23M	23A	24M	23A	23A		
			25M			
				26M		
27M	27A 28M	28A	27A	27A		

Key 1-28 Activities M - Main party, A - Associated party

Figure 9.2 Roles of participants in construction Stage A - 'Inception'

The updated framework has two pages. The first page lists the activities and the second page lists the responsible parties.

Figure 9.1 describes the activities in the construction project.

Column one is the criteria, which includes hotspot, time, cost, quality and safety.

Column two is the description of the activity. The number identifies the sequence of activity and the text is the description.

Column three is the note. 'CA' means continuous activity. These activities needed to be updated throughout the whole construction stage. 'Sub' means sub-heading activities. Certain activities are classified into a hierarchy, which consists of main activities and sub activities.

Each box in figure 9.2 identifies the number of activities and the role of the responsible parties. The number identifies the sequence of the activities and the capital letter identifies the 'status' of the responsible parties. For example, if 1A appears in the column of the project manager and 1M in the column of the client, this means that the major party responsible for activity one is the client with the project manager acting in an associated role. The major role is the leading participant for that activity, the associate participant is the supporting party for that activity.

Sometimes, the construction activities run in parallel, like activities 23, 24 and activities 27, 28. These two-pair activities are running coincidentally as the responsible parties for these two-pair activities are different.

The theoretical framework for other construction stages, that is stages B, C and D are shown in appendix seven.

In order to facilitate the participants to view their responsibilities, there is a matrix which shows the responsibilities of construction participants (see table 9.1).

	Project manager	Architect	Quantity surveyor	Structural engineer	Services engineer	Planning Superviso	Client
1 Appoint project manager	●						■
2 Statement of need	●						■
3 Project execution plan	●						■
4 Process execution plan	●						■
5 Appointment of stakeholders	●						■
5a Negiate and appoint relevant stakeholders	●	■	■	■	■		
5b Select the appropriate principal consultants	●	■	■	■	■		
5c Discuss with consultants about their terms of appointment	●	■	■	■	■		
5d Appoint relevant consultants	●	■	■	■	■		
6 Discussion of client's requirements	●		■				■
7 Inform client to discuss their job and responsibilities	●						■
8 Project brief	●						■
9 Project scope	▲						
10 Site appraisal		▲					
11 Provide guidelines on cost about achieving objectives			▲				
12 Site appraisal cost studies			▲				
13 Evaluation of finance options	●	■	■	■	■		
14 Discussion of feasibility of achieving objectives	●	■	■	■	■		
15 Determining whether the project fall into CDM Regulations	▲						
15a Appoint planning supervisor						■	●
15b Inform the client their duites under CDM Regulations						●	■
15c Contribute to Health and Safety File and Plan		■	■	■	■	●	
16 Updating feasibility plan	▲						
17 Site investigation		▲					
18 Co-ordinate consultations with local and statutory authorities	▲						
19 Consult with local authority and other statutory authorities		▲		▲	▲		
20 Provide cost advice			▲				
21 Evaluate structural implications of options and contribute to cost assessment				▲			
22 Prepare strategies and cost implications against options					▲		
23 Evaluate the feasibility plans	●	■		■	■		
24 Cost feasibility for options			▲				

● Major role
■ Associated role
▲ Single responsibilities

Table 9.1 Matrix to show the responsibilities of construction participants for Stage A -'Inception'

9.4 Added functions

Further amendments have been made on the 'aspects of interface'. These amendments focus on adding functions to the system including:

- The function of going back to the previous activity if the user chooses the wrong icon
- The function of running the construction activities in parallel, i.e. different participants do different activities at the same time
- Adding the 'reminder list' indicating what activities should be completed in the short term
- The function of recording the answer that the previous users had recorded
- Allowing the system to continue even if the user has not finished the previous activity
- Providing an interim reports during the construction stage and the final report to the user at the end of each stage
- Allowing the participant to look at their own roles and activities only
- The function of 'jump to' a specific activity

The reason for adding these functions is to improve the feasibility of the system and make it better at replicating a real-world situation. Sometimes, the user cannot provide a definite answer on whether the activity is finished; therefore, it is a good idea to add these functions so as to help the user.

9.5 New structure

The updated CONBPS breaks down the construction stages into different files. Each construction stage consists of three files. Because of limitation of time, only construction stage A 'Inception' has been finished for demonstration and testing purposes. It has three knowledge-based systems, which are 'CONBPS_A', 'A_All' and 'A_Main'. As each construction stage has three separated knowledge-based systems, there is an independent 'introduction' file which gives the brief description of these knowledge-based systems.

9.5.1 CONBPS_A

'CONBPS_A' comprises of all the construction activities in construction stage A. It is suitable for the project manager or other participants who are interested in the overall construction process. The operation of this file is similar to the old version. It lists the construction activities in sequence. The users answer whether they have finished the previous activity. If the answer is 'yes', or 'processing', then they proceed to the next activity. The user should answer 'yes' if they have completed that activity. If they have started that activity but it has not yet been completed, they should answer 'processing'. If the user answers 'no', the system will ask them whether they would like to continue or not. If the user does not want to continue, the system will list the report of this stage and then it will end.

9.5.2 A_All

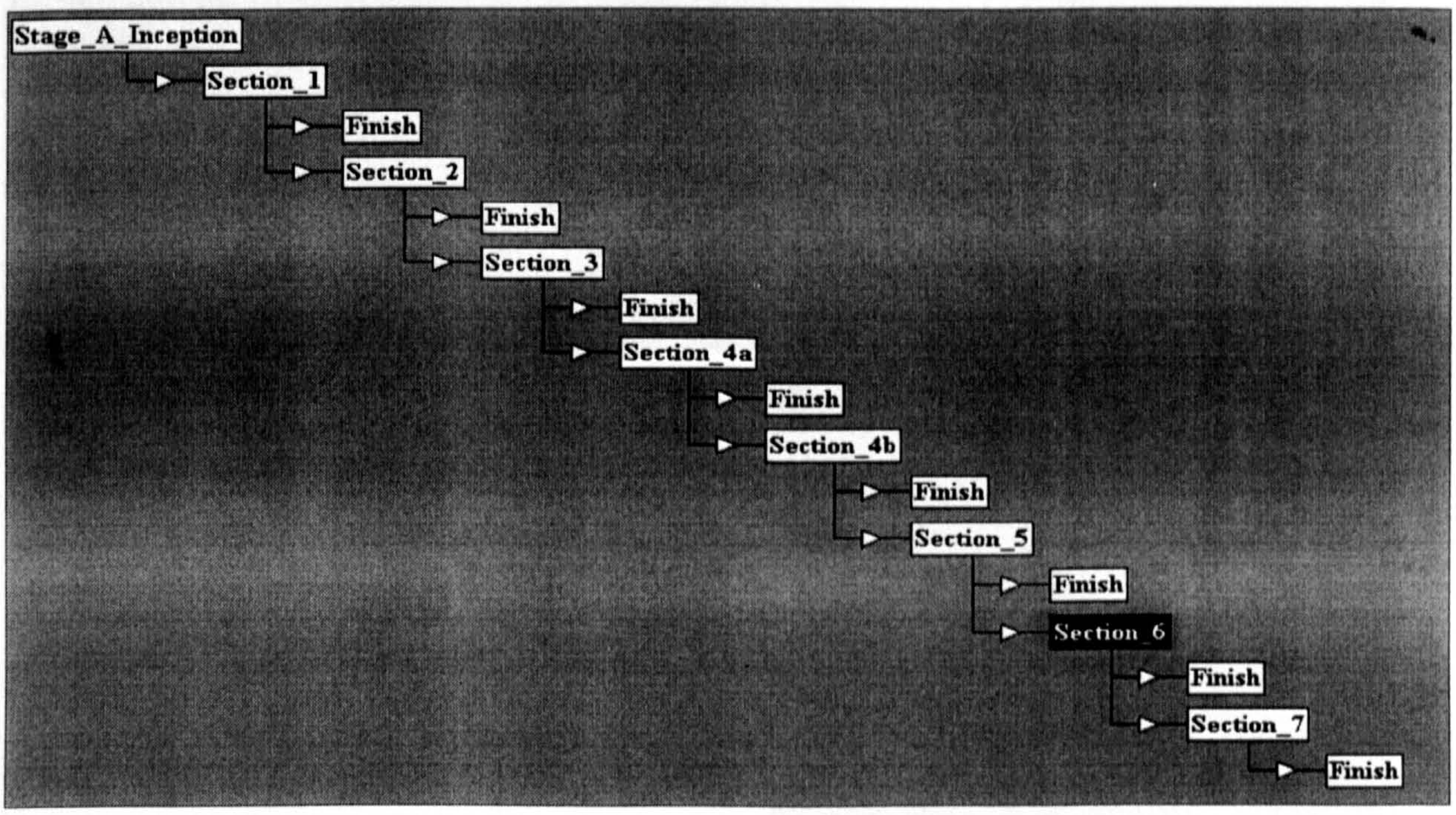
'A_All' comprises of the construction activities with reference to the responsible parties in construction stage A. This file is suitable for users who intend to check the responsibilities of a particular party. The user can choose a specific role about which they would like to know more. For example, if you choose 'project manager', then it will only show the activities which should be done by the project manager. This file will show all the activities which are the responsibility of the project manager, either they are acting as a 'major role' or as an 'associated party'.

9.5.3 A_Main

'A_Main' classifies the construction activities with reference to the major responsible parties in the construction stage A. These files only show the activities which relate to the parties which acted as the major party.

9.6 Knowledge representation structure

Figure 9.3 is the map of updated CONBPS_A. As there are many activities, it is more convenient to build-up and debug if it is divided into several sections. Each section is linked to finish individually as it aims to allow the system to stop at any point.



Remark: Section 1: Activities 1 to 4; Section 2: Activities 5 to 8; Section 3: Activities 9 to 12; Section 4a: Activities 13 to 14c; Section 4b: Activities 14d to 16; Section 5: Activities 17 to 20d; Section 6: Activities 21 to 24; Section 7: Activities 25 to 28

Figure 9.3 Map of CONBPS_A

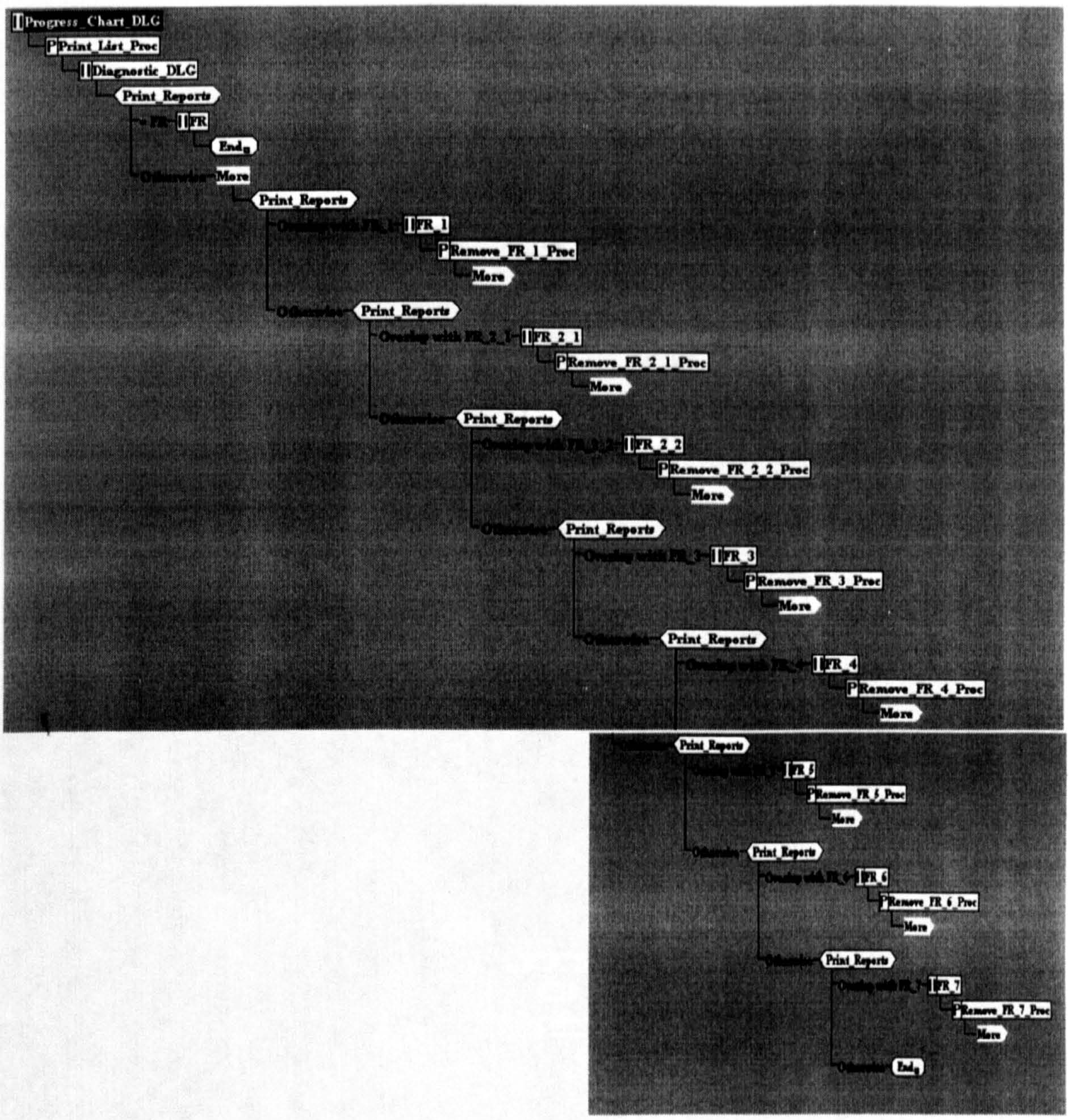


Figure 9.4 Decision tree of CONBPS_A – Finish

Figure 9.4 shows the decision tree of 'Finish'. The aim of this decision tree is to link the 'Report'. No matter where the project stops at, it will still link to the report section.

CONBPS_A has the function of asking whether the project has a project number. The aim is to save the record of the answers of the project. If the user answers 'Yes', then it will open the record of the previous answer. On the other hand, if the user answers

‘No’, the system will ask the user to give the project number for this operation. After finishing the current operation, it will update the current record.

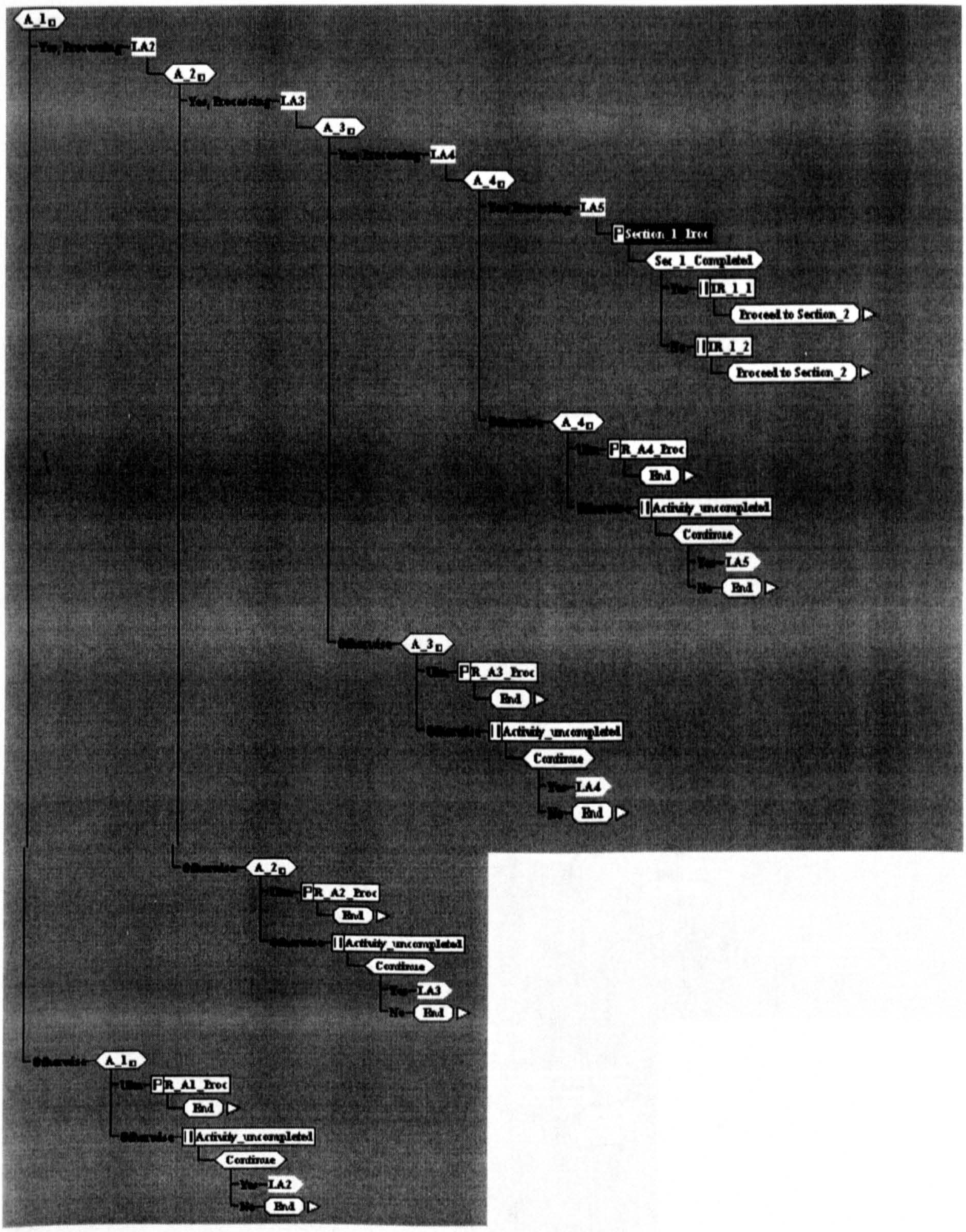


Figure 9.5 Decision tree of CONBPS A – Section 1

Figure 9.5 shows a part of the decision tree of section 1 of CONBPS_A. The activities are listed in a sequence. Each activity is represented in one box; the text of each activity is described in an attached 'dialogue box'. If the answer to an activity is 'yes' or 'processing', it will proceed to the next activity. If the answer to an activity is 'no, it will proceed to an 'Activity uncompleted' statement. Also, it will allow the user to have the option to end the project or not. The operation of the system will be discussed in section 9.7 in greater detail.

In order to achieve some looping or setting of the activities, some 'procedures' need to be set. In order to differentiate, there is a 'P' attached to the activity box. Under certain circumstances, a label is needed to be attached in order to perform certain functions. The label is the grey colour box in the decision tree.

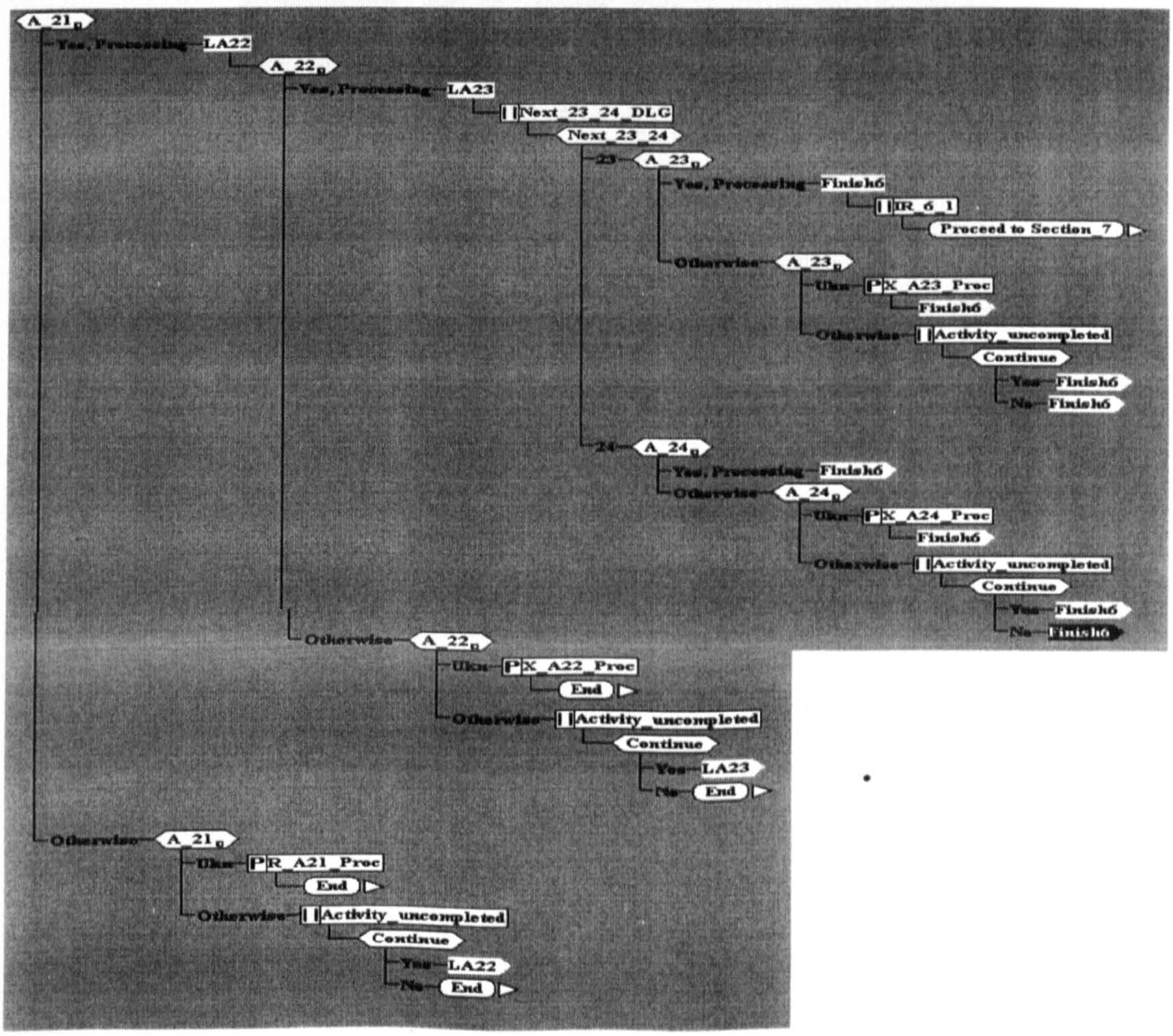


Figure 9.6 Decision tree of CONBPS_A – Section 6

Figure 9.6 shows the section 6 of CONBPS_A. Activities 23 and 24 are operating at the same time, and that means the system should ask the user whether they are doing activity 23 or 24 at a certain time. This section has set up the procedure for performing this function, that is the split of the decision tree after activity 22.

The other decision trees of 'CONBPS_A' have been shown in appendix nine.

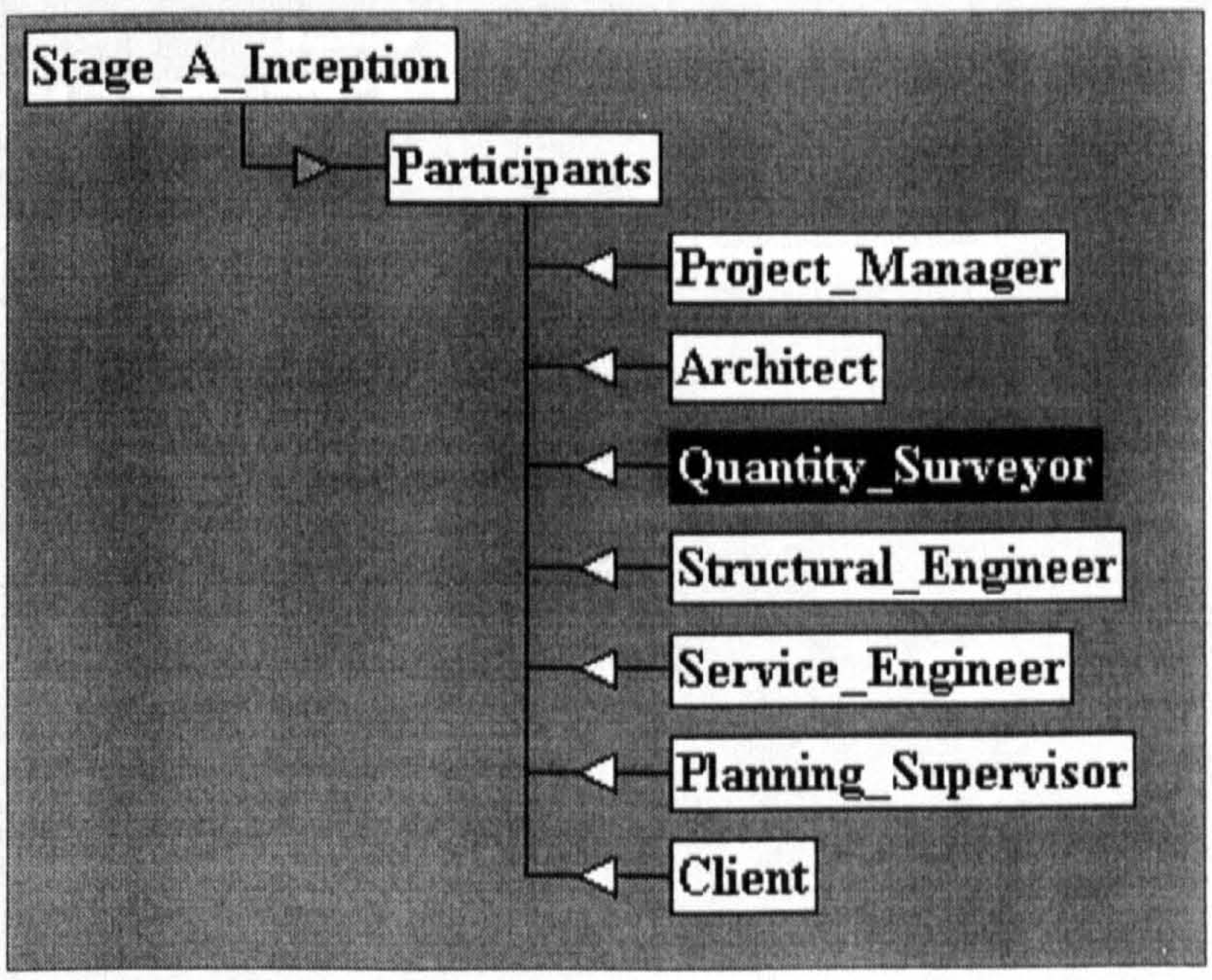


Figure 9.7 Map of A_All

Figure 9.7 shows the map of A_All. The aim of this file is to allow individual participants to see what activities that they are involved in.

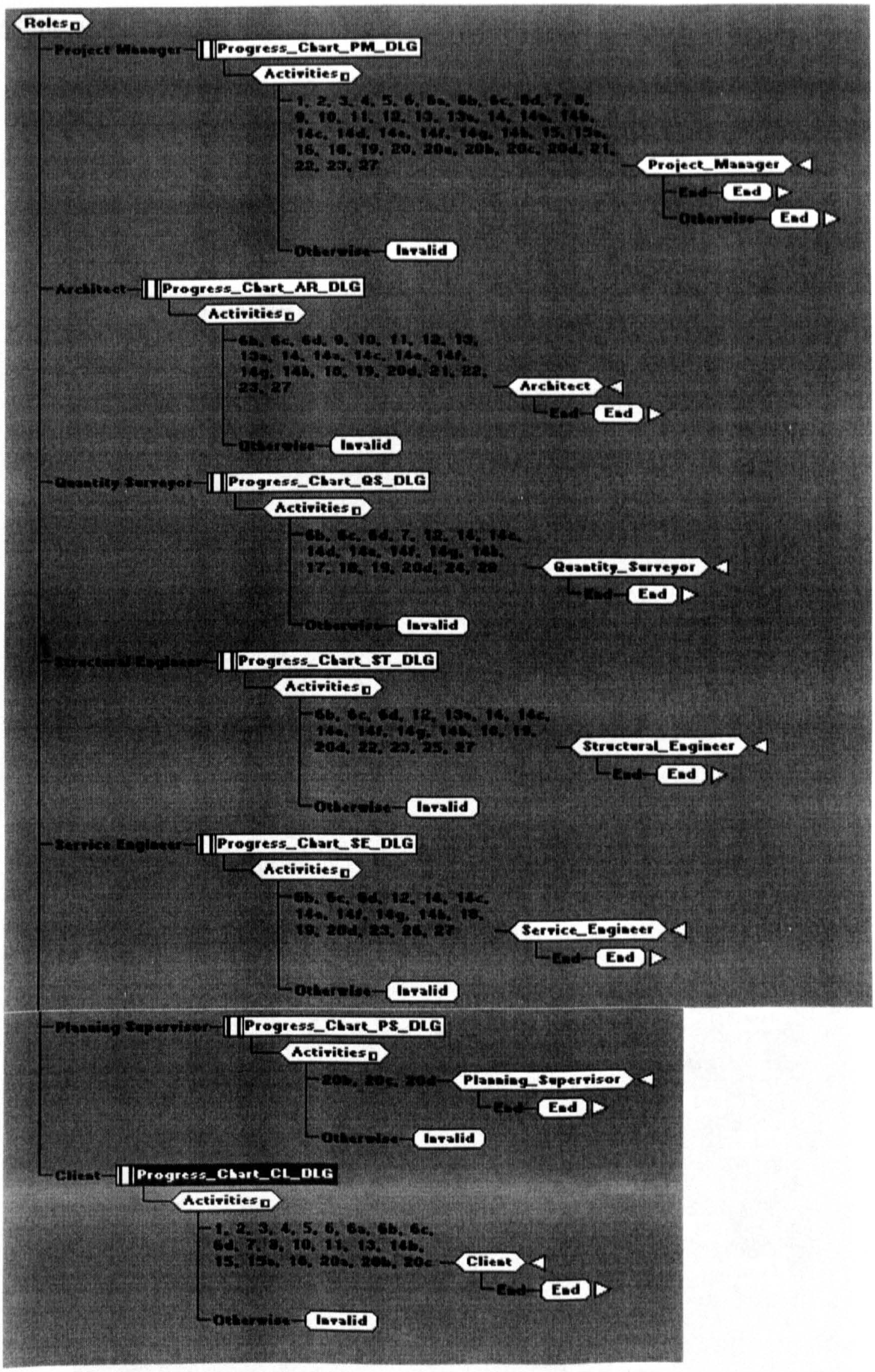


Figure 9.8 Decision tree of A_All – Participants

Figure 9.8 is the decision trees for A_All participants. It shows all the activities which are the responsibility of each participant. Besides, each participant is linked to his or her relevant report and their list of activities.

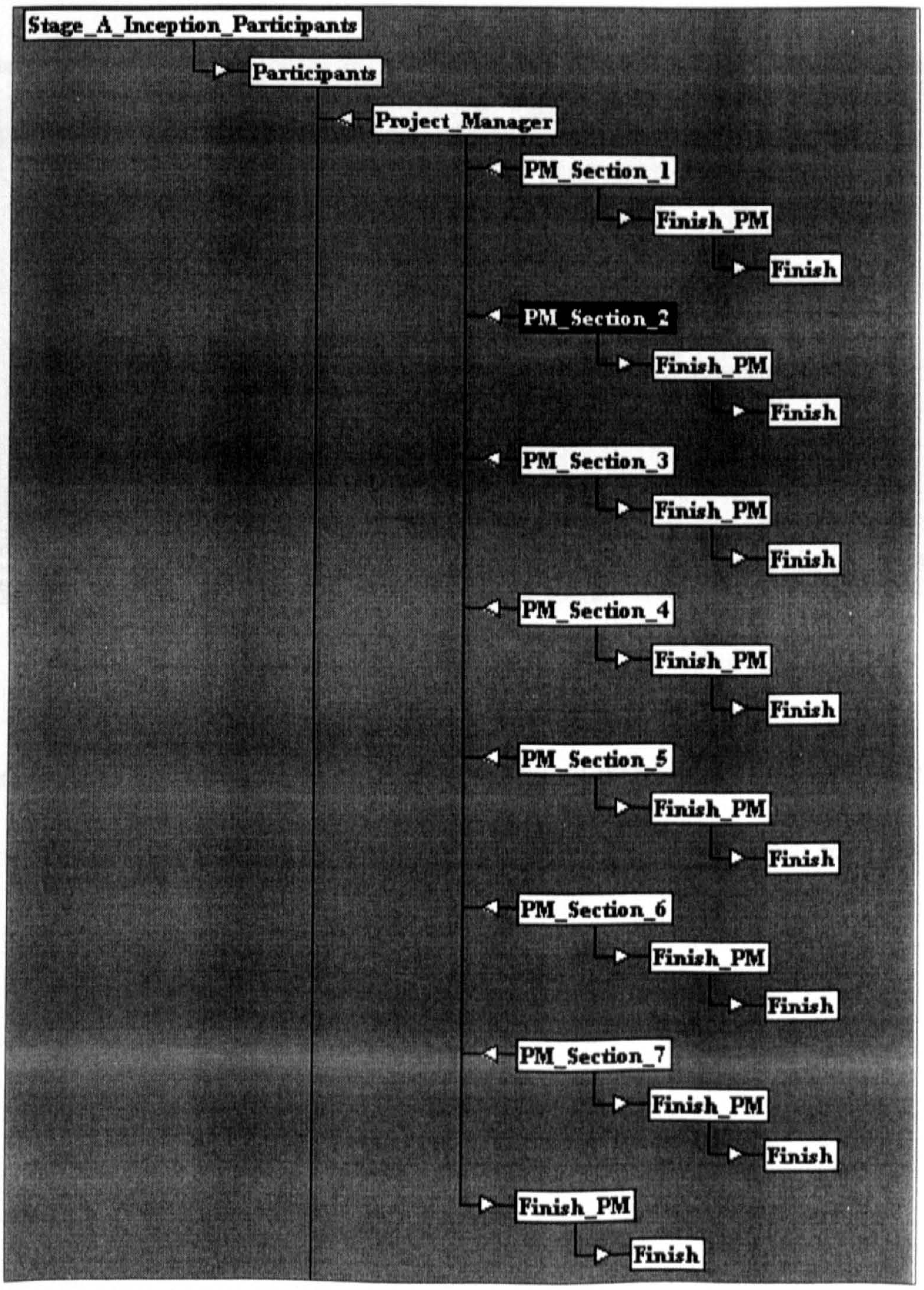


Figure 9.9 Map of participant 'Project Manager'

Figure 9.9 shows the detailed description of the map for the project manager. As there are many activities, it is better to divide the activities into small sections. Also, each section is linked to the 'finish' so as to let the users go to the end of the operation at any time.

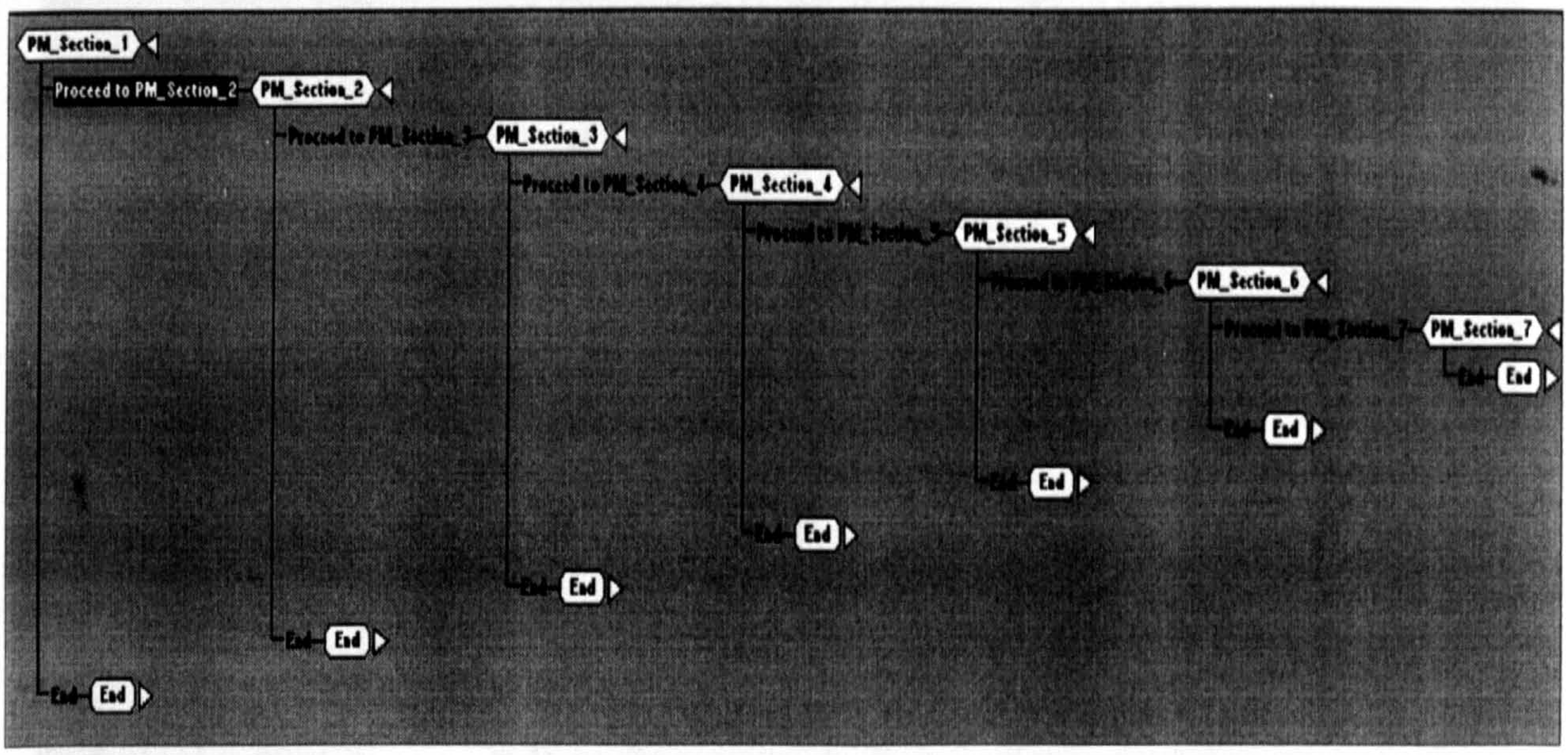


Figure 9.10 Decision tree of A_All – Project Manager (Section)

Figure 9.10 shows the decision tree for the project manager. As with the decision tree for the others, it also proceeds from one stage to the next until it has been ended.

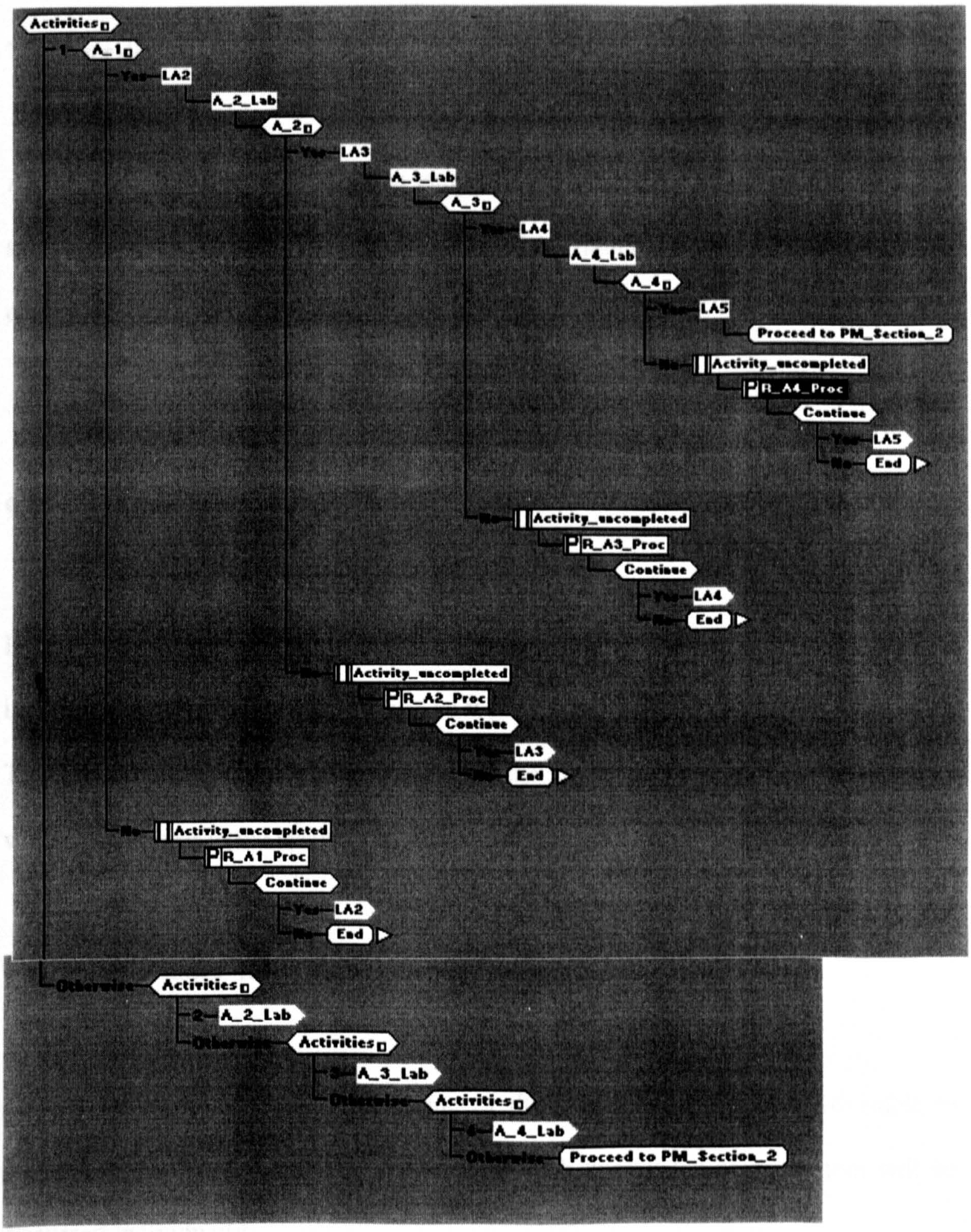


Figure 9.11 Decision tree of activities for project manager – Section 1

Figures 9.11 shows the decision tree of section 1 activities for the project manager. As the user should be able to choose any activity, apart from 'yes' or 'no', it should add the 'otherwise' section in order to achieve this purpose.

The other decision trees of A_All have been shown in appendix ten.

As the basic operation of A_Main is same as A_All, therefore, it will not be discussed separately in this section. The decision trees of A_Main have been shown in appendix eleven.

9.7 Operating process

Before proceeding to the independent process file, it is advisable to run the independent 'Introduction' file at first as it gives a brief overview of these three files. This file will provide the brief description of the system, definition of the terminology which will appear in the system and its basic operation.

The screen of 'Intro' file is shown in appendix eight.

After finishing viewing the explanation in the introduction file, it is advisable to proceed to the 'core' files. The operation of each knowledge-based system will be discussed individually.

'CONBPS_A' is the knowledge-based system which shows the construction process in a sequential order. The first screen for this file is the introductory screen (see figure 9.12).

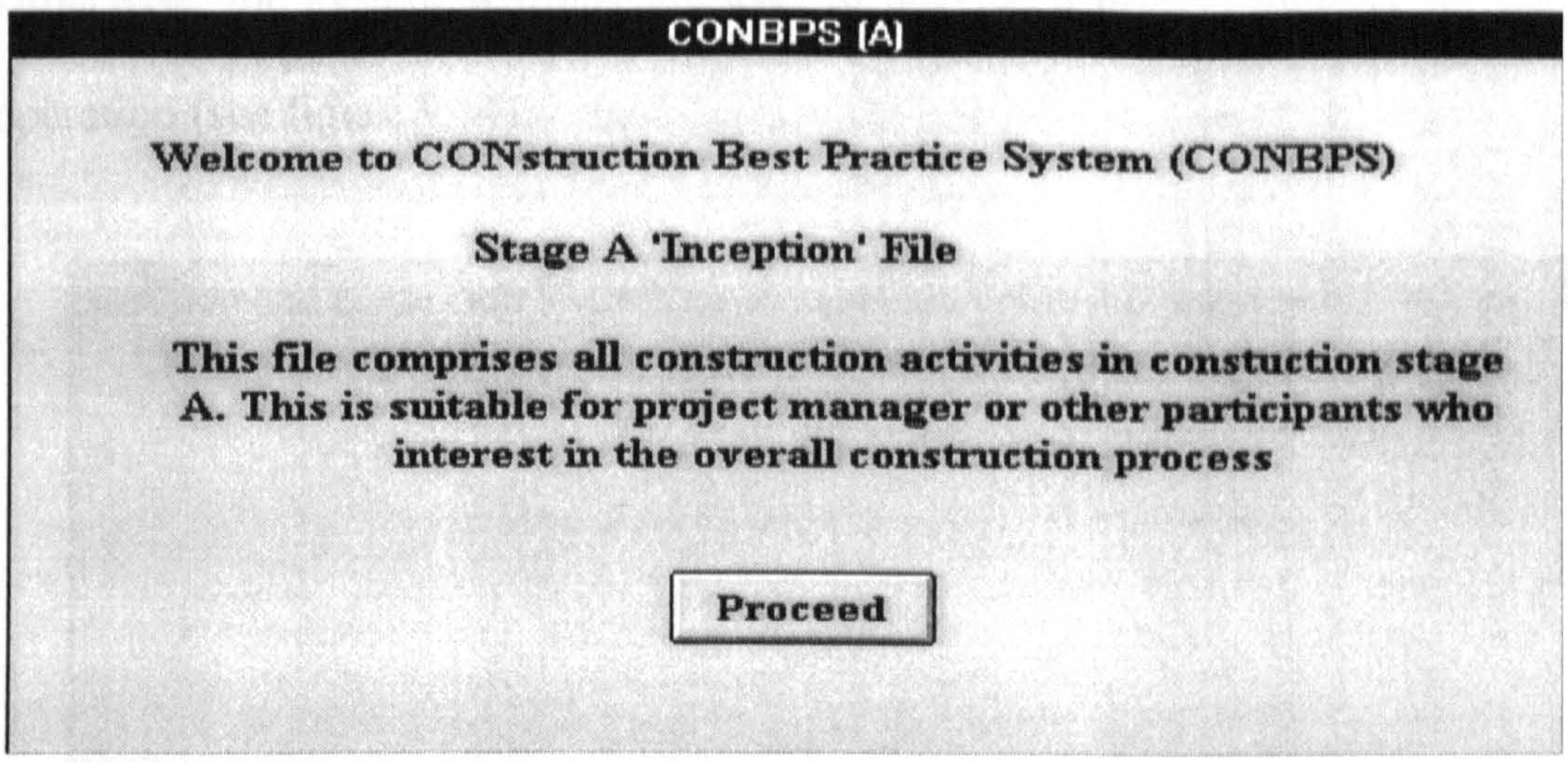


Figure 9.12 The introductory screen of CONBPS_A

The next screen asks whether this project has a project number. If it is an old project, it should have a project number (see figure 9.13). The user chooses 'yes' icon, then it will open the file which saved the previous record. For example, if the previous operation stopped at activity 4, then the system will start at activity 5 if it is opened again. The answer of the previous operation was saved in the report. The function of the report will be further discussed at the later section.

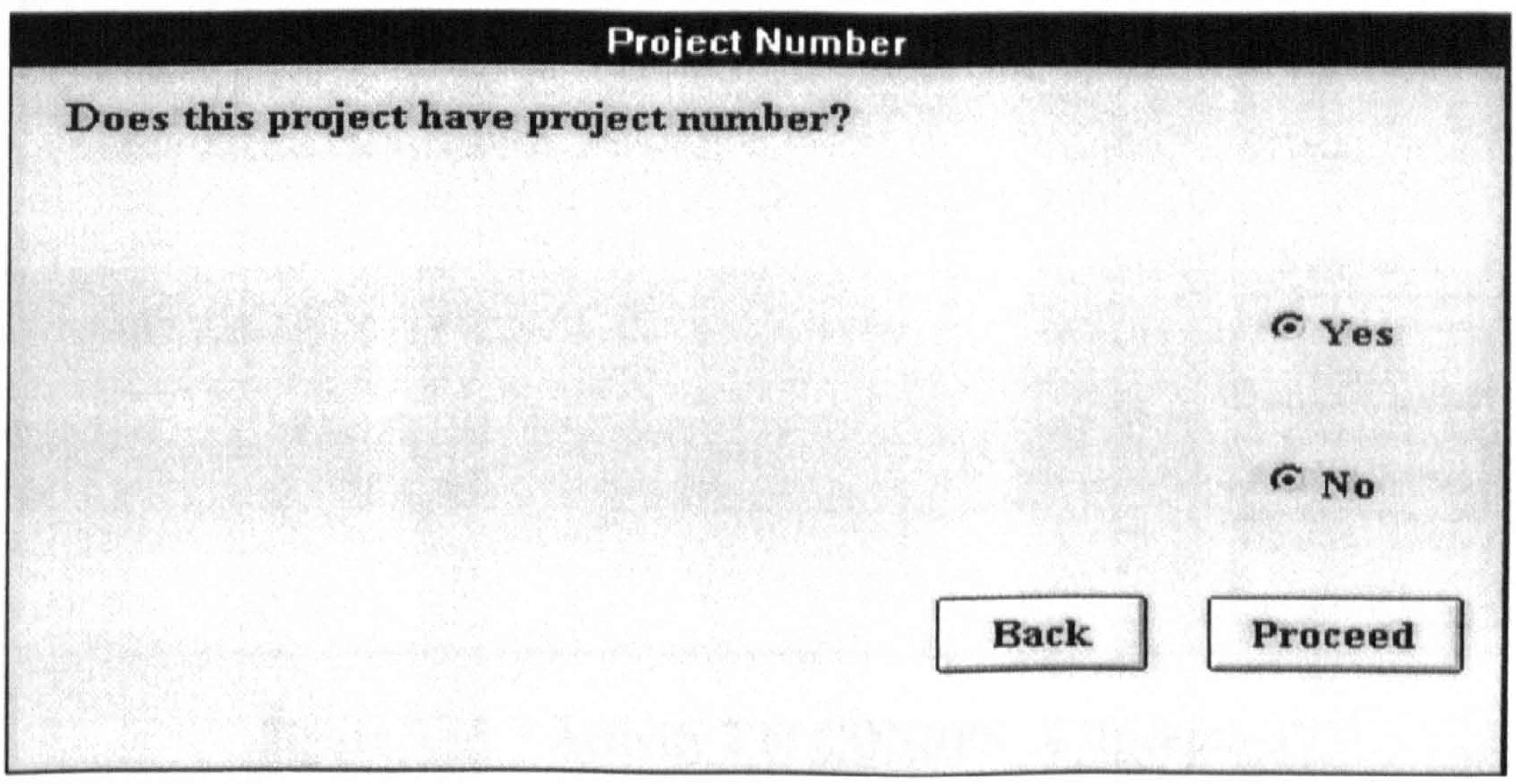


Figure 9.13 The screen which asks for the 'Project Number'

Otherwise, the system will ask the user to provide a project number for the current operation (see figure 9.14).

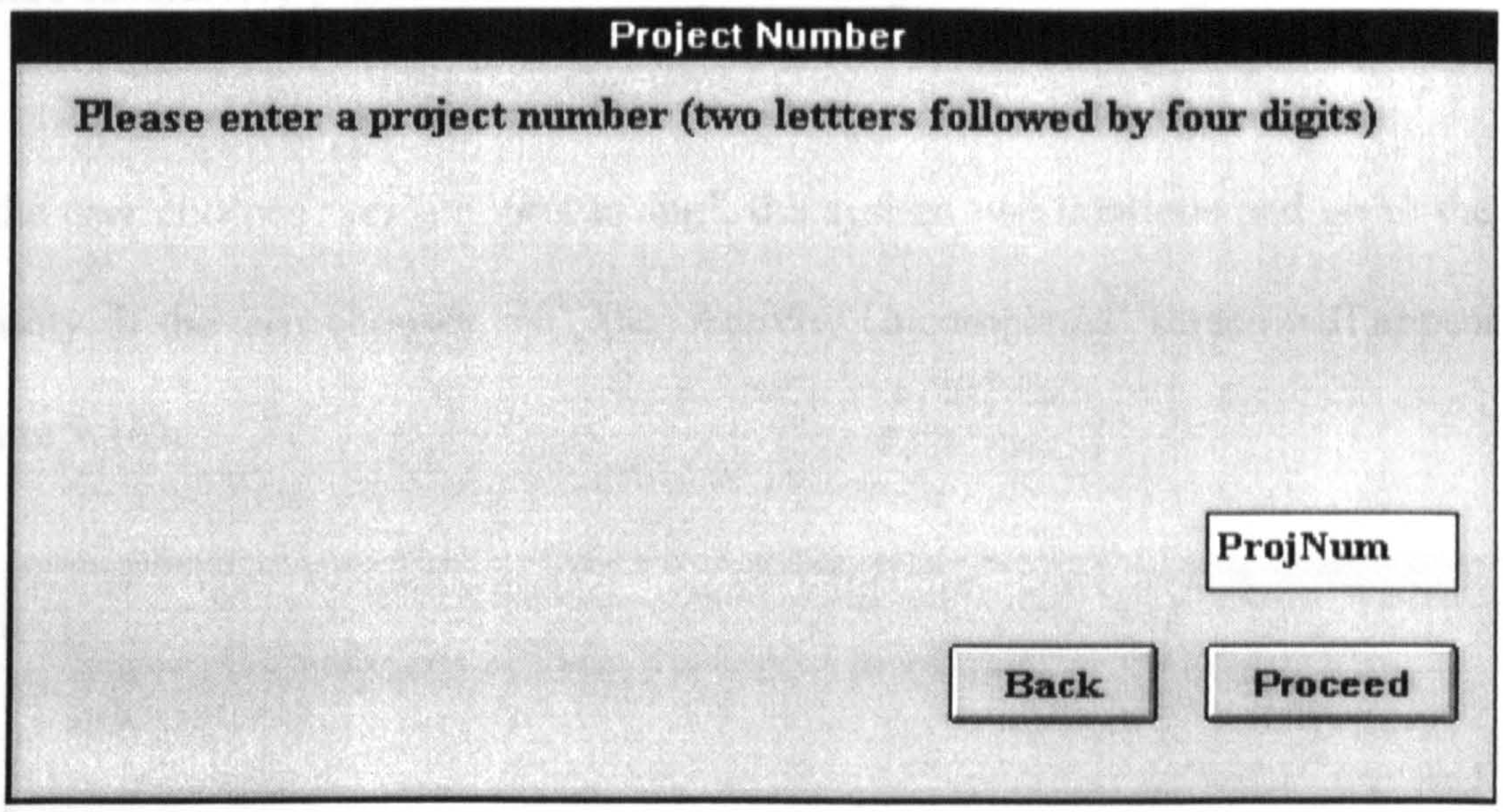


Figure 9.14 The screen which asks the user to enter 'Project Number'

After asking for the background information for the project, the system will start to state the activities. Figure 9.15 shows activity two of stage A.

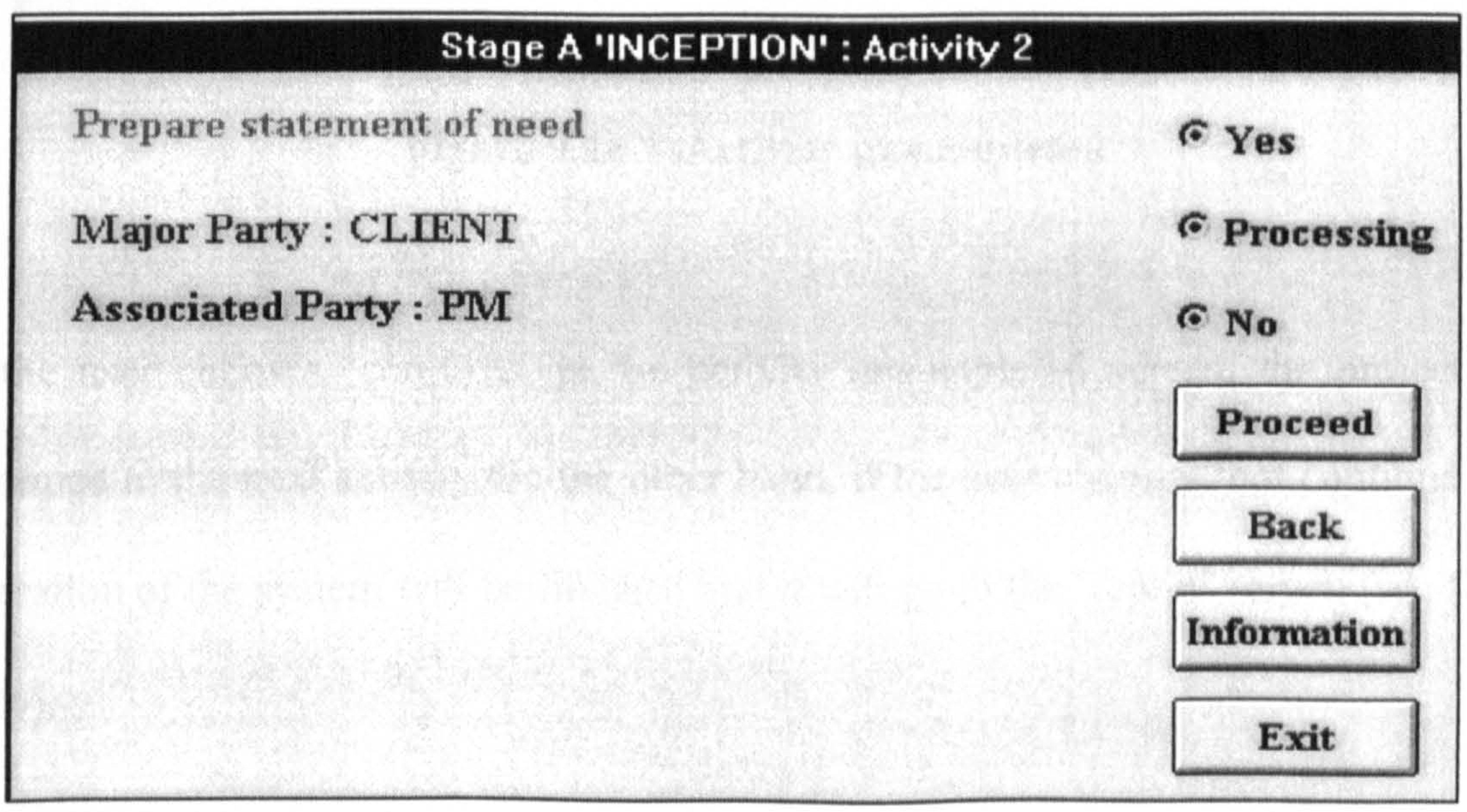


Figure 9.15 Activity 2 of CONBPS_A 'Inception'

In order to help the user, the current stage and the current activity has been clearly stated in each screen. The major party and the associated party are mentioned. As this activity is the 'hotspot' activity, the whole sentence is pink. The 'hotspots' are the 'critical activities', to which each participant should pay special attention in order to ensure satisfactory performance before proceeding to the next stage.

If the user chooses 'yes' or 'processing', the system will continue and go to the next activity. If the user chooses 'no', the 'Activity Uncompleted' screen will appear (see figure 9.16).

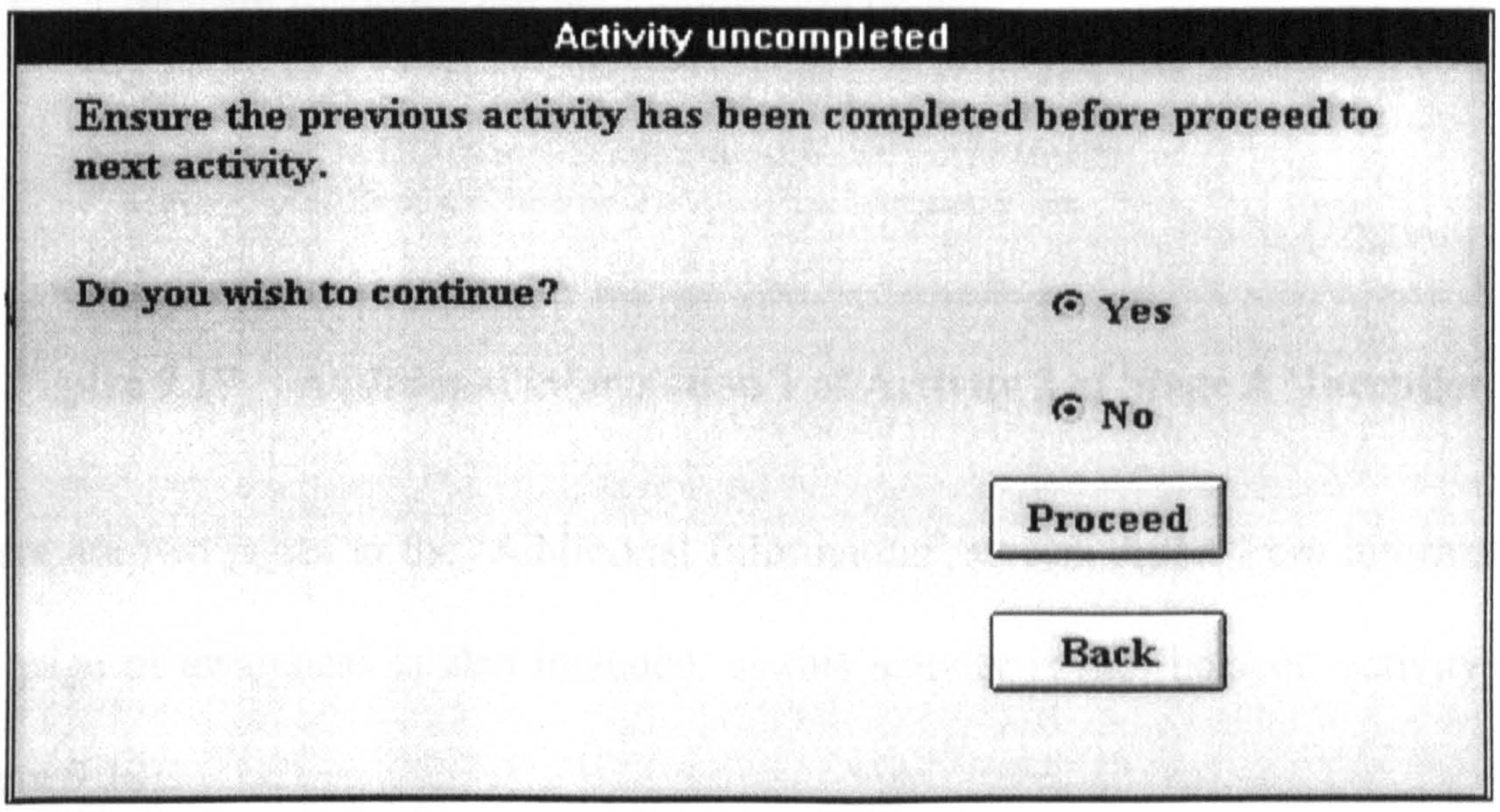


Figure 9.16 Activity uncompleted

If the user chooses 'continue' in the activity uncompleted screen, the project will continue to the next activity On the other hand, if the user chooses 'not continue', the operation of the system will be finished and it will go to the 'report' screen (see figure 9.24).

Additionally, there is also the explanatory facility which has been built into the system. Other than 'yes' or 'no', the user can choose the icon 'information' (see figure 9.17). This icon provides an explanation of the terminology and additional information about the project.

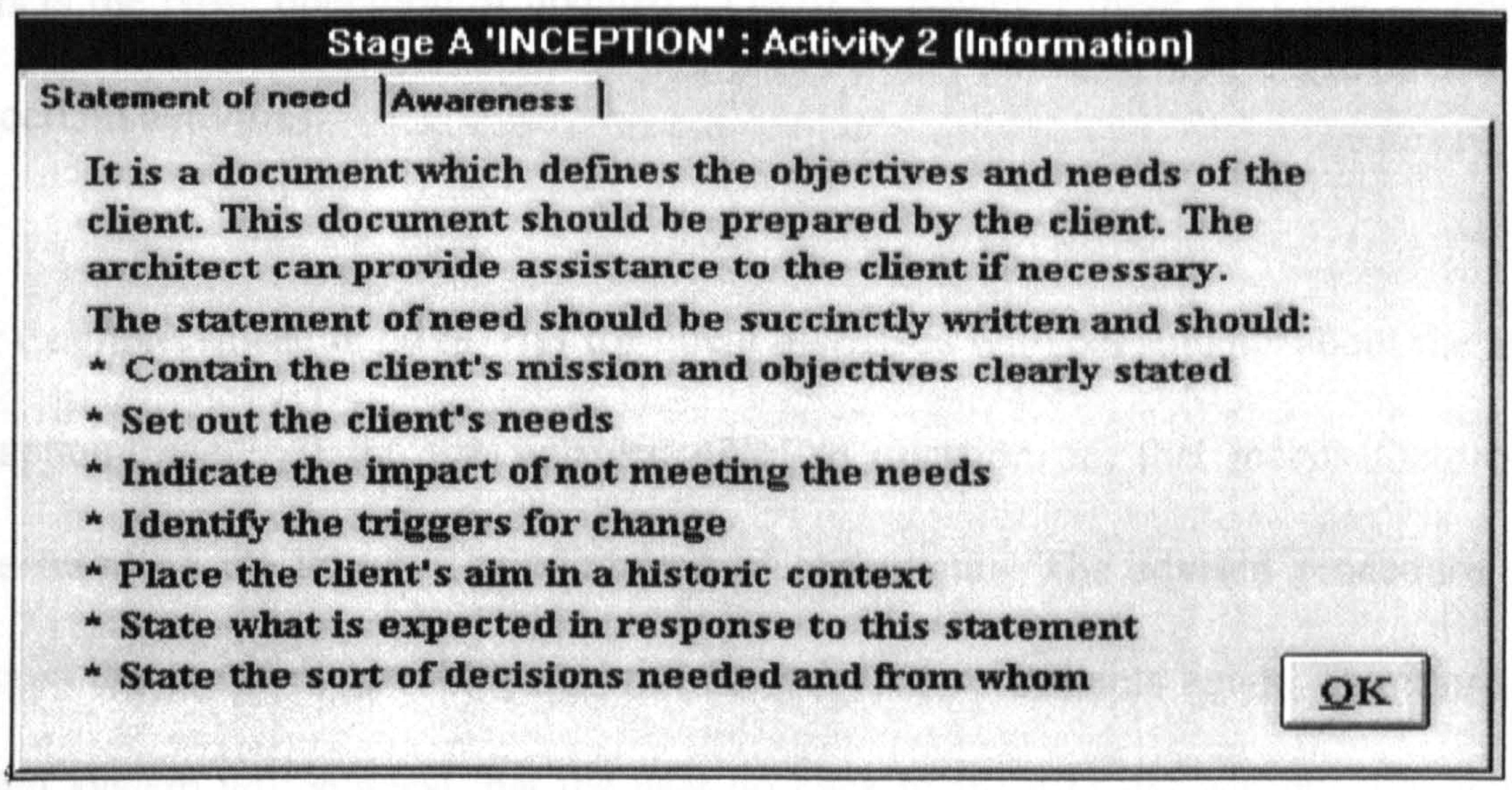


Figure 9.17 Additional information 1 of Activity 2 of Stage A 'Inception'

There are two pages in the 'Additional Information' screen. Apart from information, the page of awareness is also included, as this activity is the 'hotspot' activity (see figure 9.18).

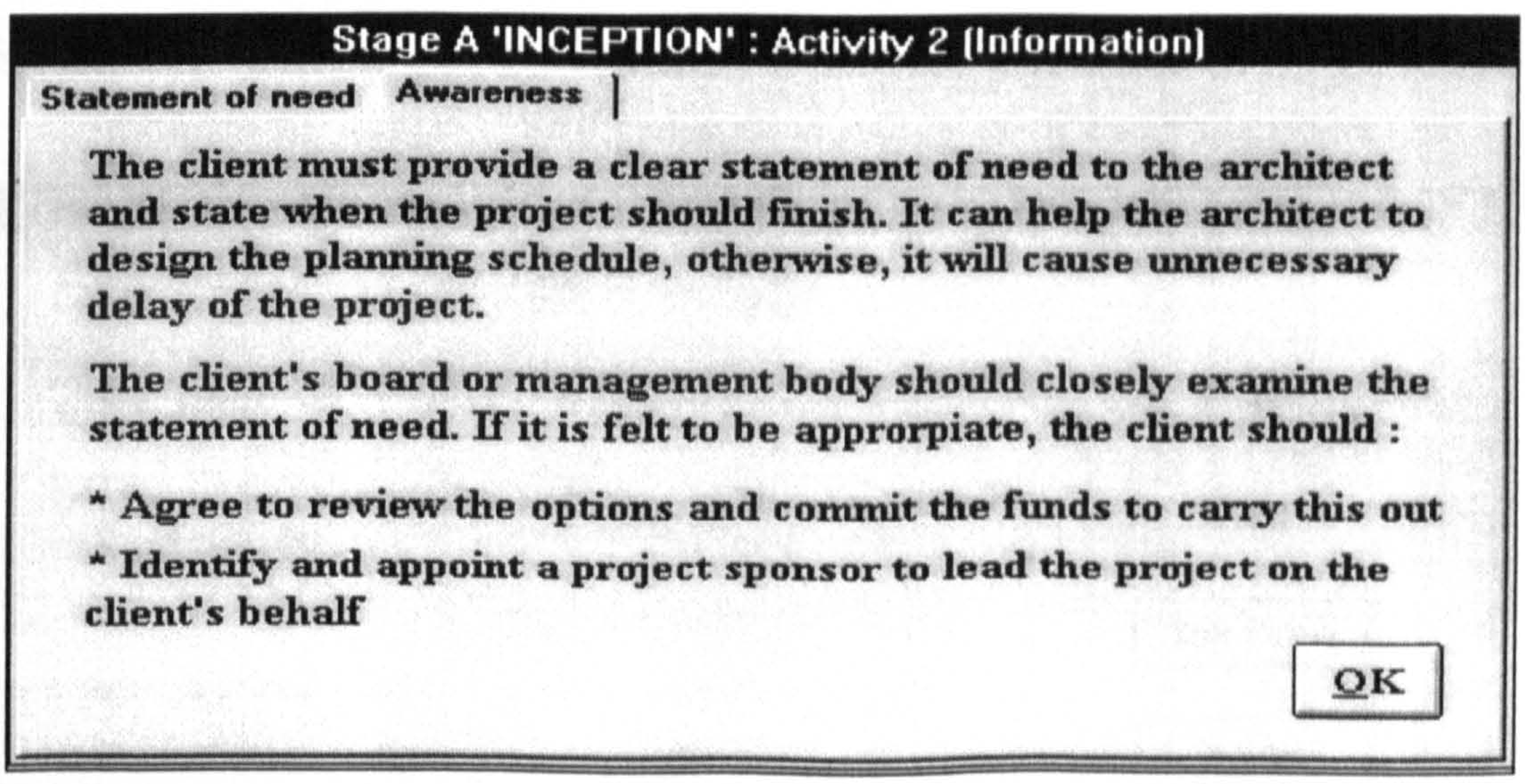


Figure 9.18 Additional information 2 of Activity 2 of Stage A 'Inception'

If the user chooses 'exit', the system will go to the report (see figure 9.24). It will show the record of the answer for the activities.

This is the basic operation of updated CONBPS; however there are some exceptions on certain activities.

For example, question 6d is 'Has the client discussed with consultants about the terms of appointment?' If the user answers 'No' to question 6d, that means there is no agreement on the terms of appointment of consultants. The advised procedure is to discuss the terms of appointment with the selected consultants again. Therefore, the expert system will suggest that the user go back to the relevant activity, i.e. activity 6a.

Another example is activities 23 and 24. These two activities are operated at the same time, and the system will ask which activity they are interested in (see figure 9.19). If the user chooses activity 23, then it will go to activity 23. Otherwise, it will go to activity 24.

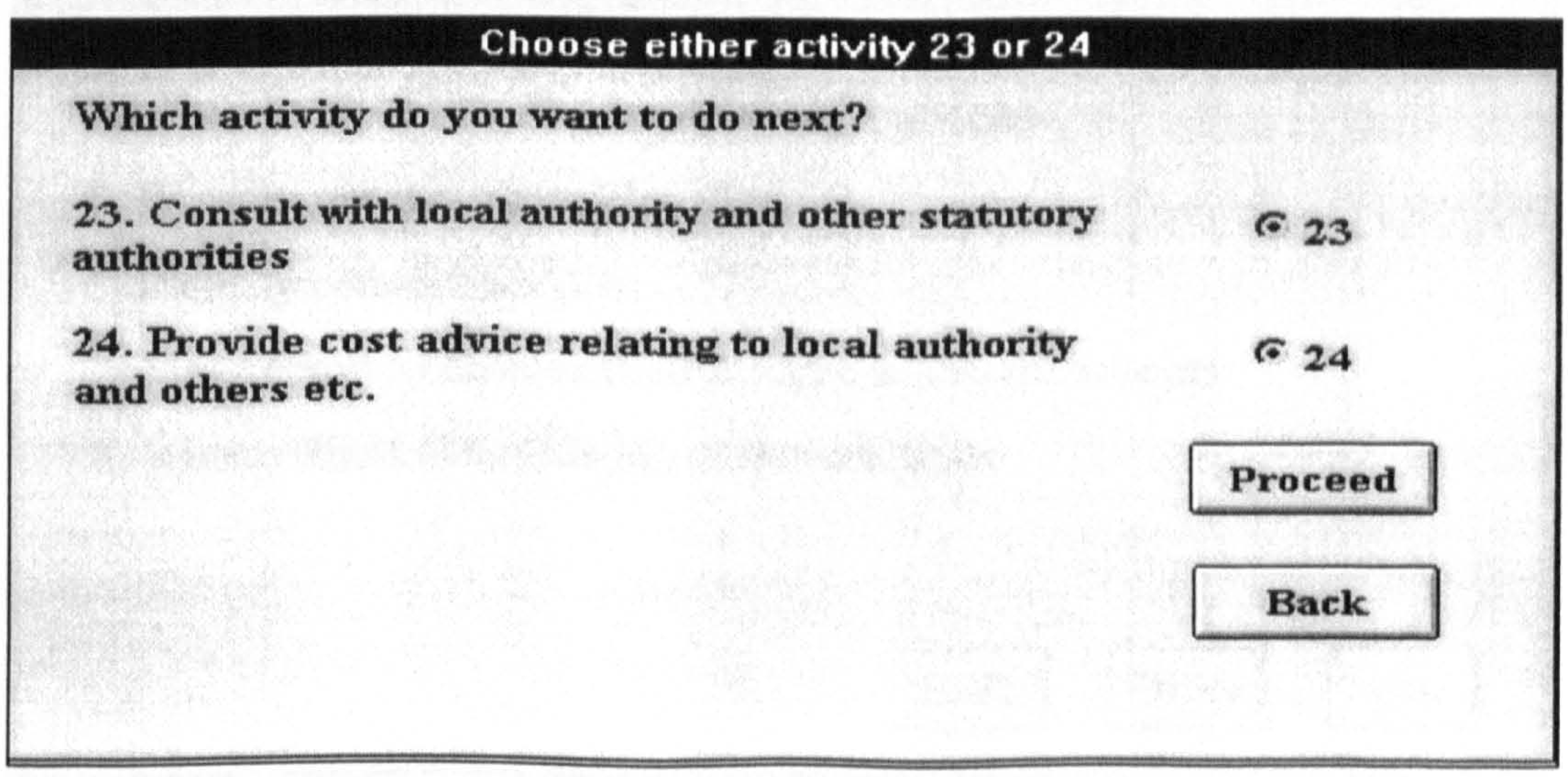
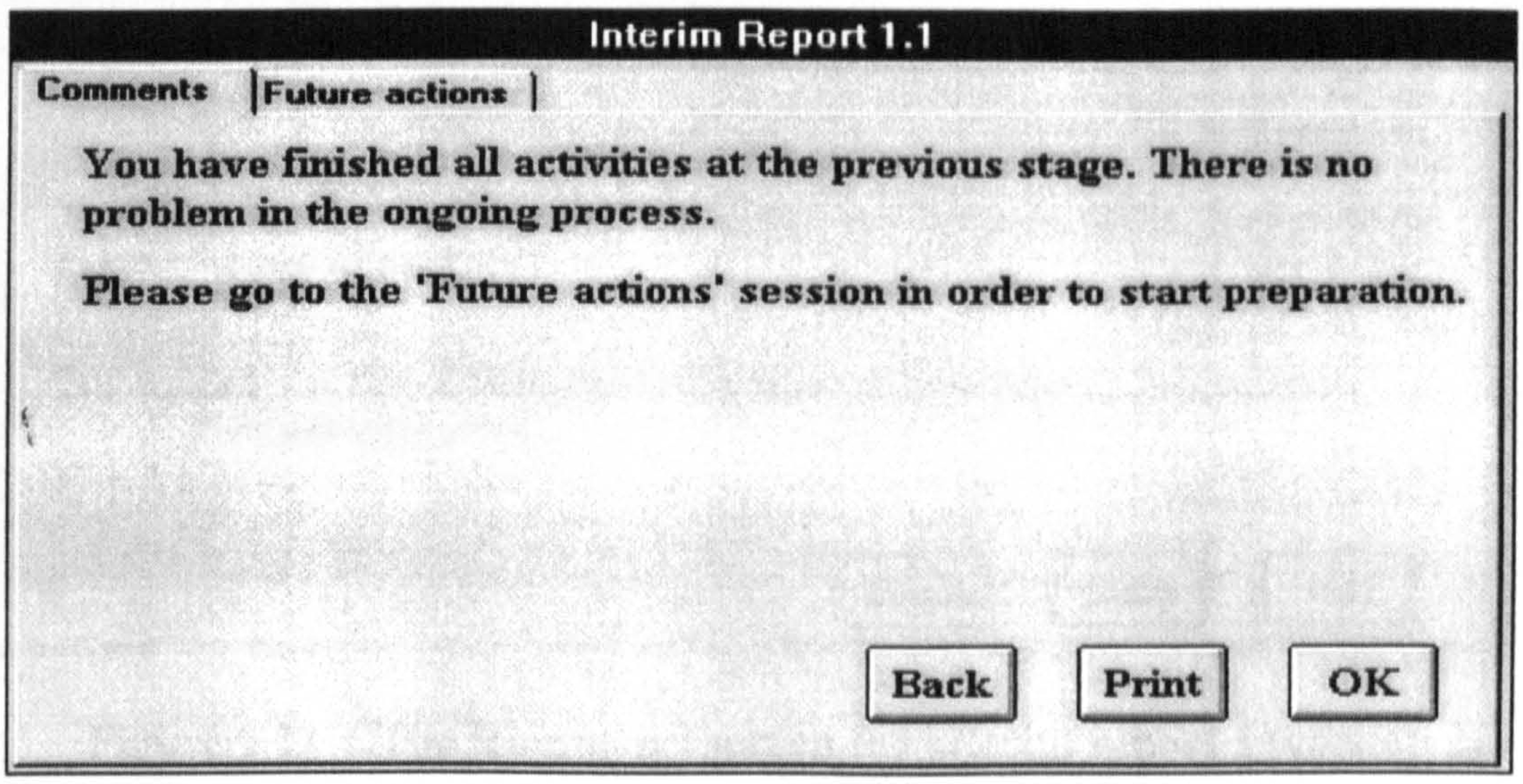


Figure 9.19 The screen for choosing to proceed to either activity 23 or 24

As mentioned in section 6.4, the system will provide interim reports and final reports. The relationship between the activities and the reports is dynamic. Based on the answer of the users to the system, CONBPS provides different interim and final reports.

With regard to interim report, it will be shown after finishing every four activities.



Remark: The activities in stage A is divided into seven sections, each section has four activities. Interim report 1 is related to activities 1 to 4.

Figure 9.20 The 'comment' screen for interim report 1 (version 1)

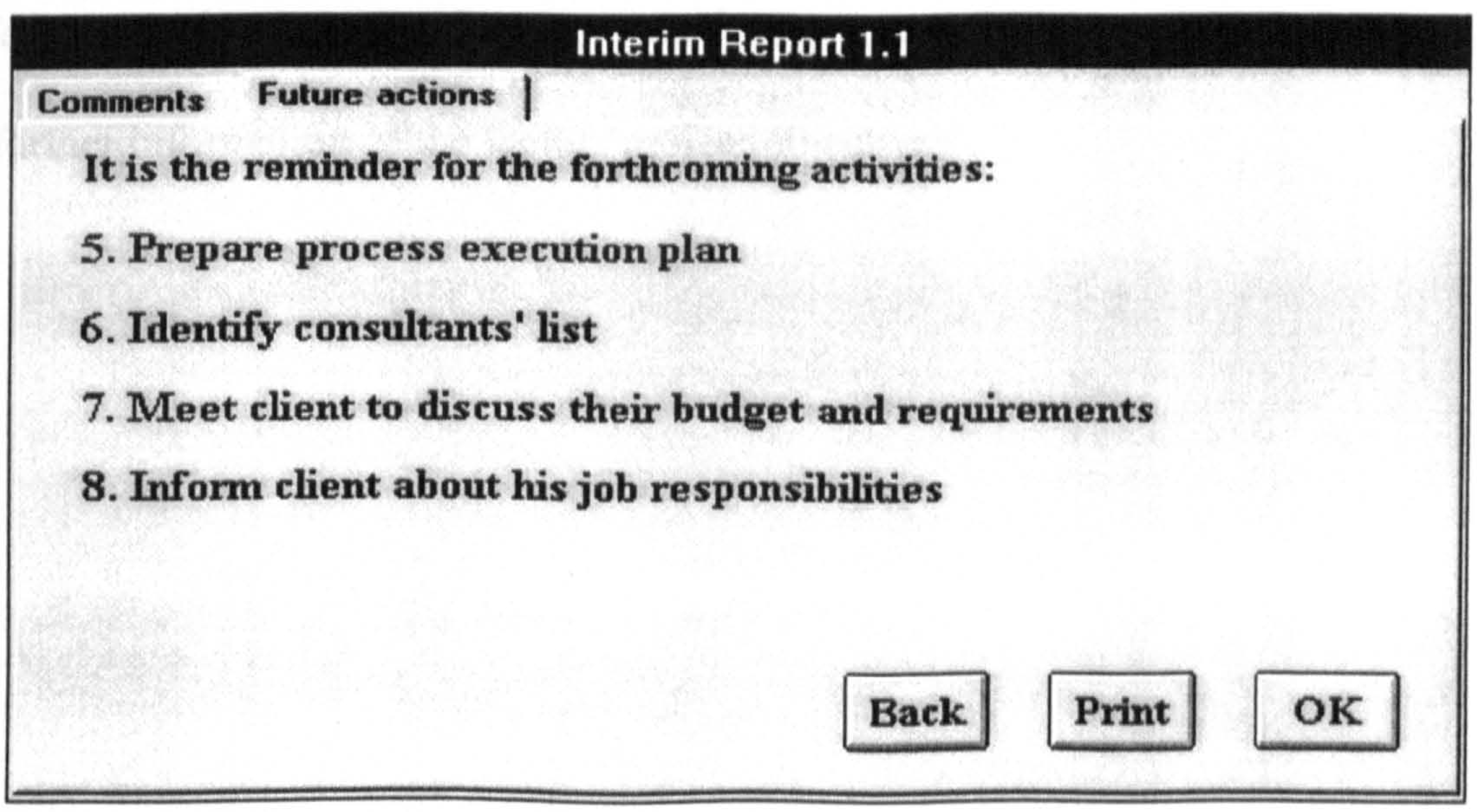


Figure 9.21 The 'future actions' screen for interim report 1

Figures 9.20 and 9.21 are the screen for interim report 1, which relates to activities 1 to 4. It consists of two screens, and the first screen shown will be based on the answer for the activities. Figure 9.20 is the screen which will be shown if the user has finished all activities. Figure 9.21 is the reminder for the future actions. It lists what are the activities that need to be done in the coming future.

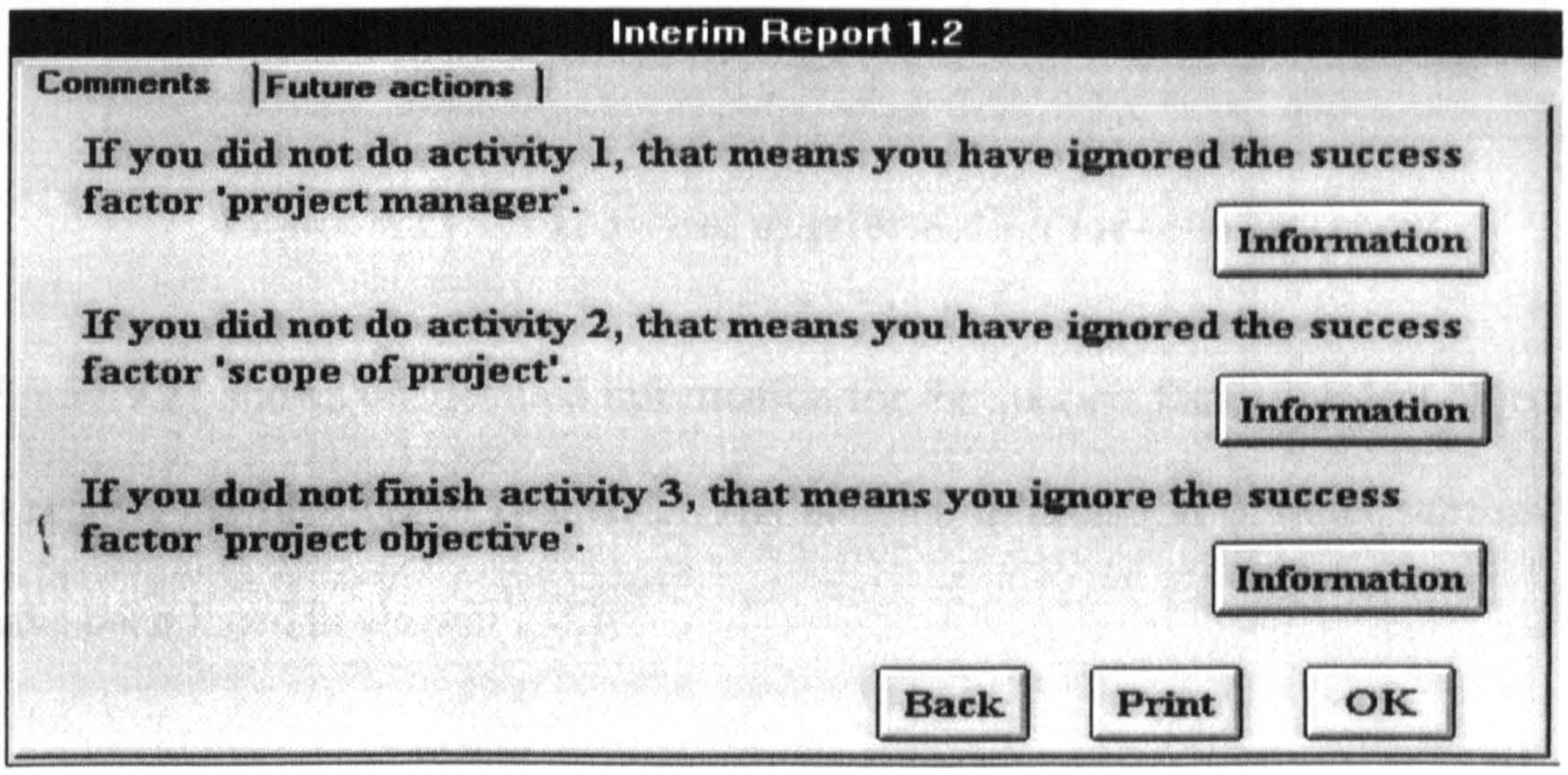


Figure 9.22 The 'comment' screen for interim report 1 (version 2)

Figure 9.22 will be shown if the user does not finish some activities in section 1. It will list which success factor is related if they do not finish a certain activity. The 'information' icon links to the screen on further information. Figure 9.23 is the screen on further information of the factor 'project objectives'.

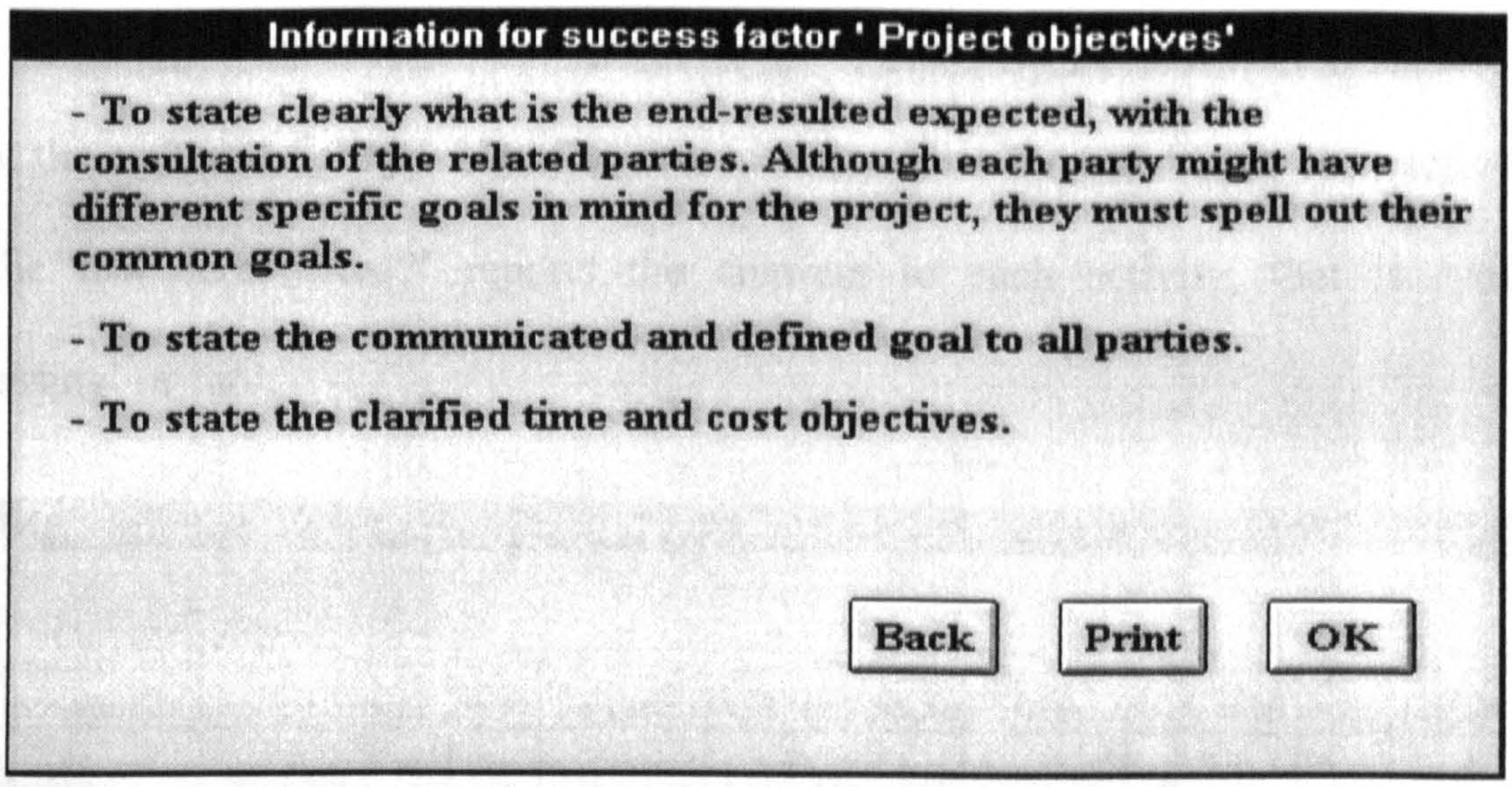


Figure 9.23 The screen of information for interim report

Figure 9.23 shows the detailed information for the success factor 'project objectives'. It reports the findings of chapter 2. The detailed information of other success factor have been listed in chapter 2.4.1.

The relationship between the factors and the activities is shown in table 9.2. The reasons for choosing these factors is because their relationship to the activities is straightforward.

Table 9.2 Success factors and the related activities

Success factor	Activity
Project Manager	1. Appoint a project manager
Scope of project	2. Prepare a statement of need 11. Establish the project scope
Project objective	3. Assisting the client in order to identify the objectives
Project team	6. Identify consultants' list
Communication and information management	12. Communicate to the consultants about the requirements of the Client's Brief
Control	14. Set up targets and monitoring procedures for the Project
Health and Safety	20. Determine whether the project falls within the CDM Regulations

After finishing the operation of the process, the system will provide the report to the user at the end (see figure 9.24). The row 'activity' lists the number of each activity and the row 'completed?' reports the answers to each activity, that is 'yes', 'processing' or 'no'.

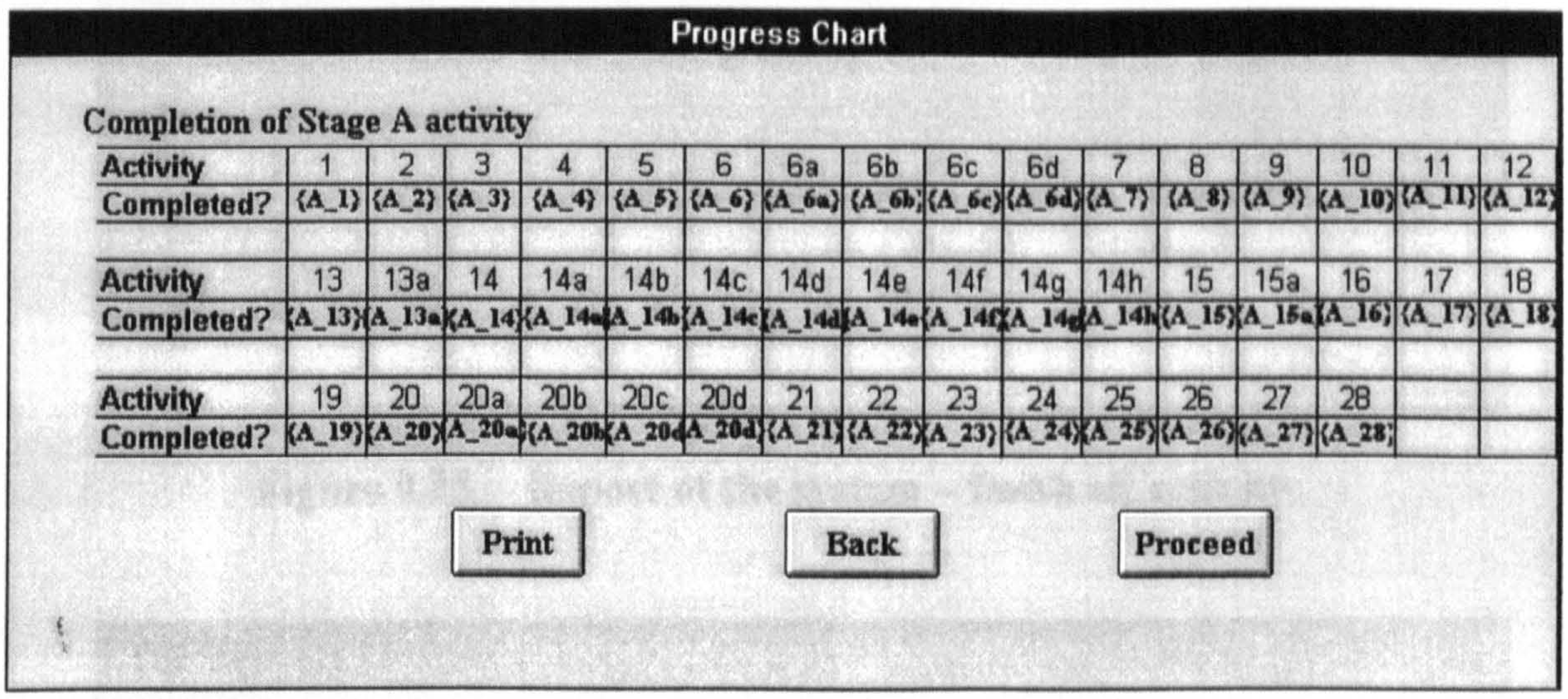


Figure 9.24 Report of the system

If this is the first time for operating the system, the activities which are unanswered will be left blank. If this is a second time for operation, the activities which are still unanswered will be filled as 'Ukn' as the system requires some default value for the unanswered question, therefore, it will show 'Ukn' to classify that it is an unanswered activity.

Apart from simply reporting the answers of the user, the report section will also identify if the user has ignored key issues in their response. Figures 9.25 to 9.27 show the first level reports of the system.

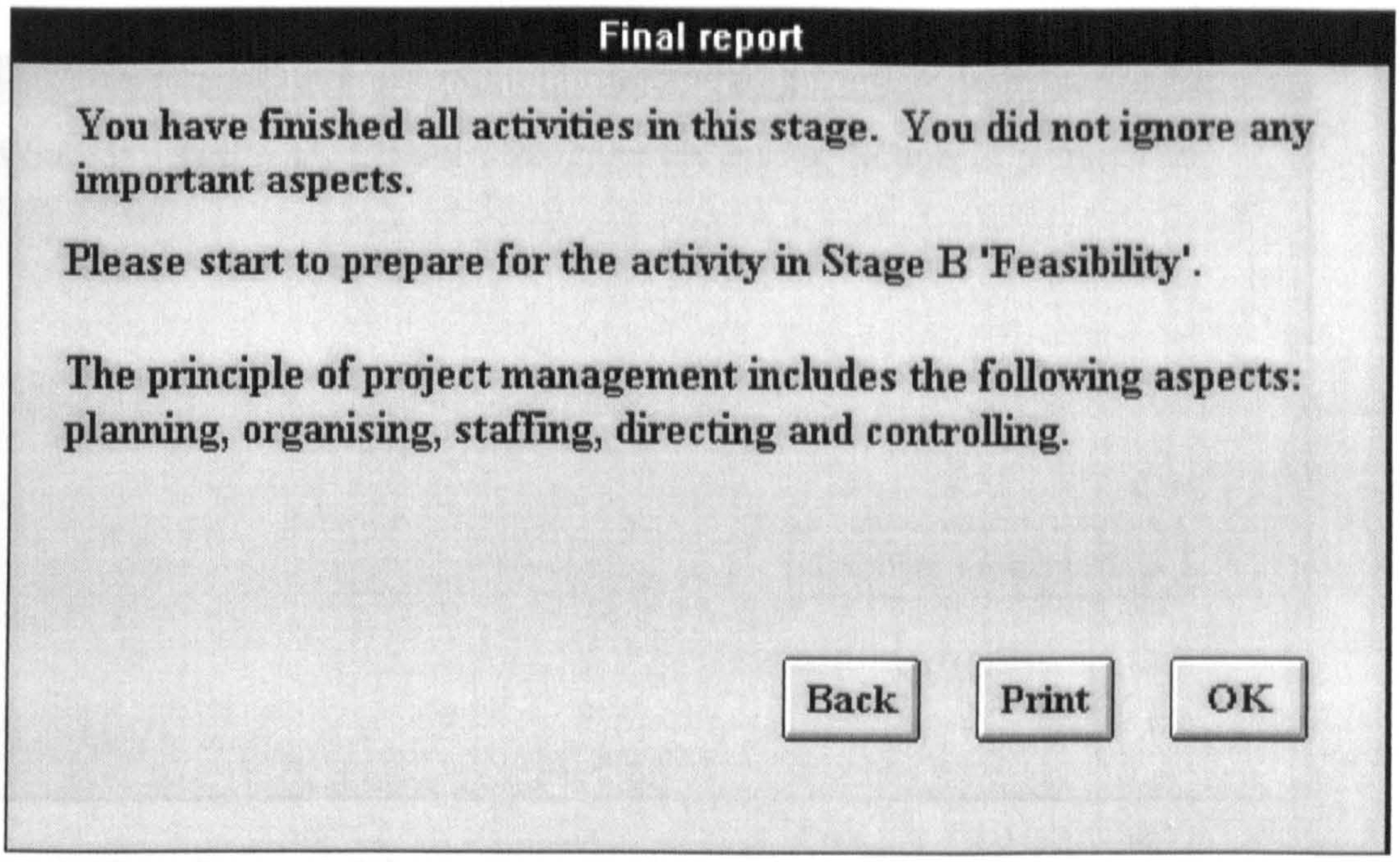


Figure 9.25 Report of the system – finish all activity

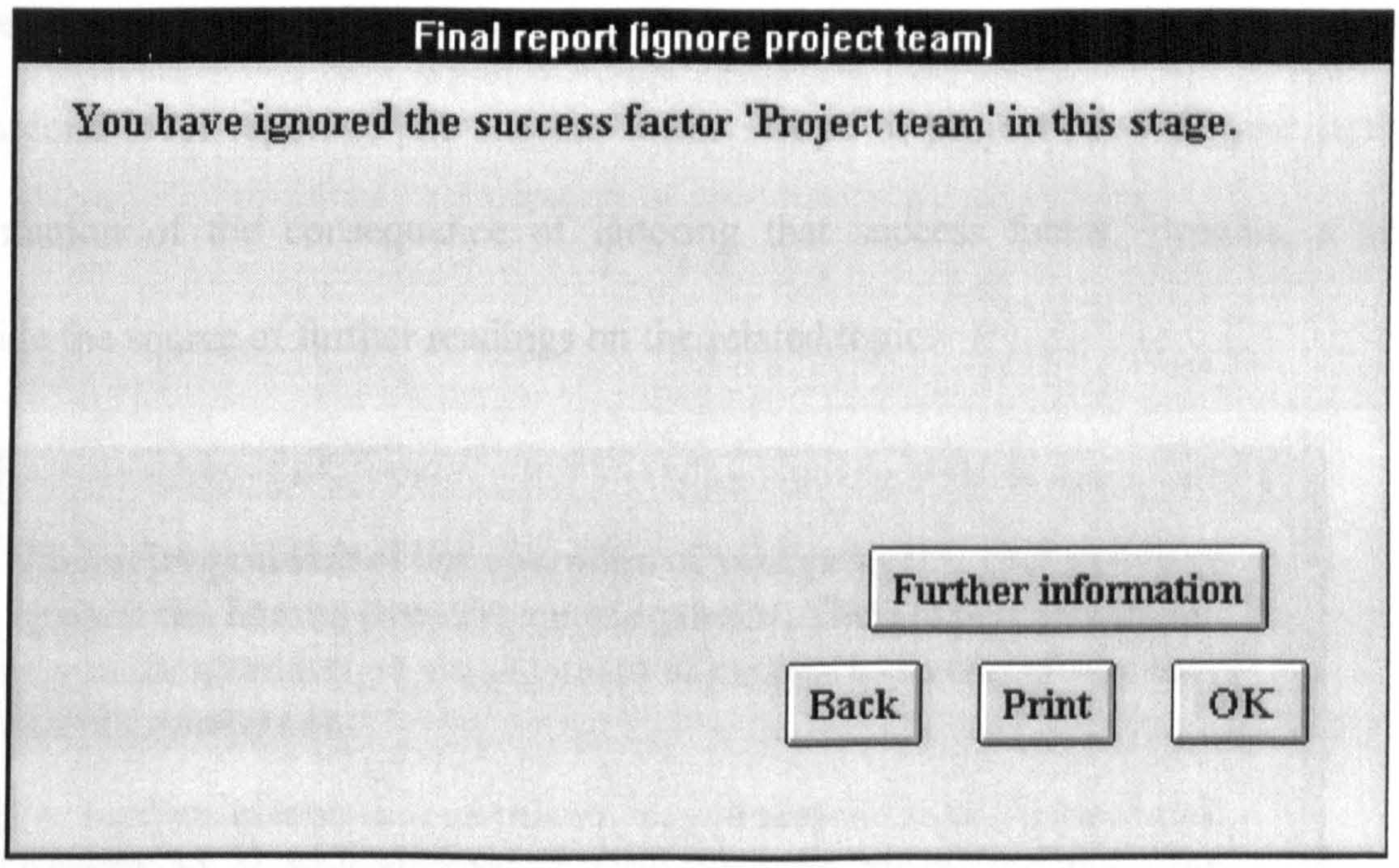


Figure 9.26 Report of the system – ignore success factor ‘project team’

Figure 9.25 will be shown when the user has finished all activities. Figure 9.26 will be shown if the user does not finish the activities which is related to success factor ‘project team’. Figure 9.27 will be shown if the user ignores the activities that relate to one success factor repetitively.

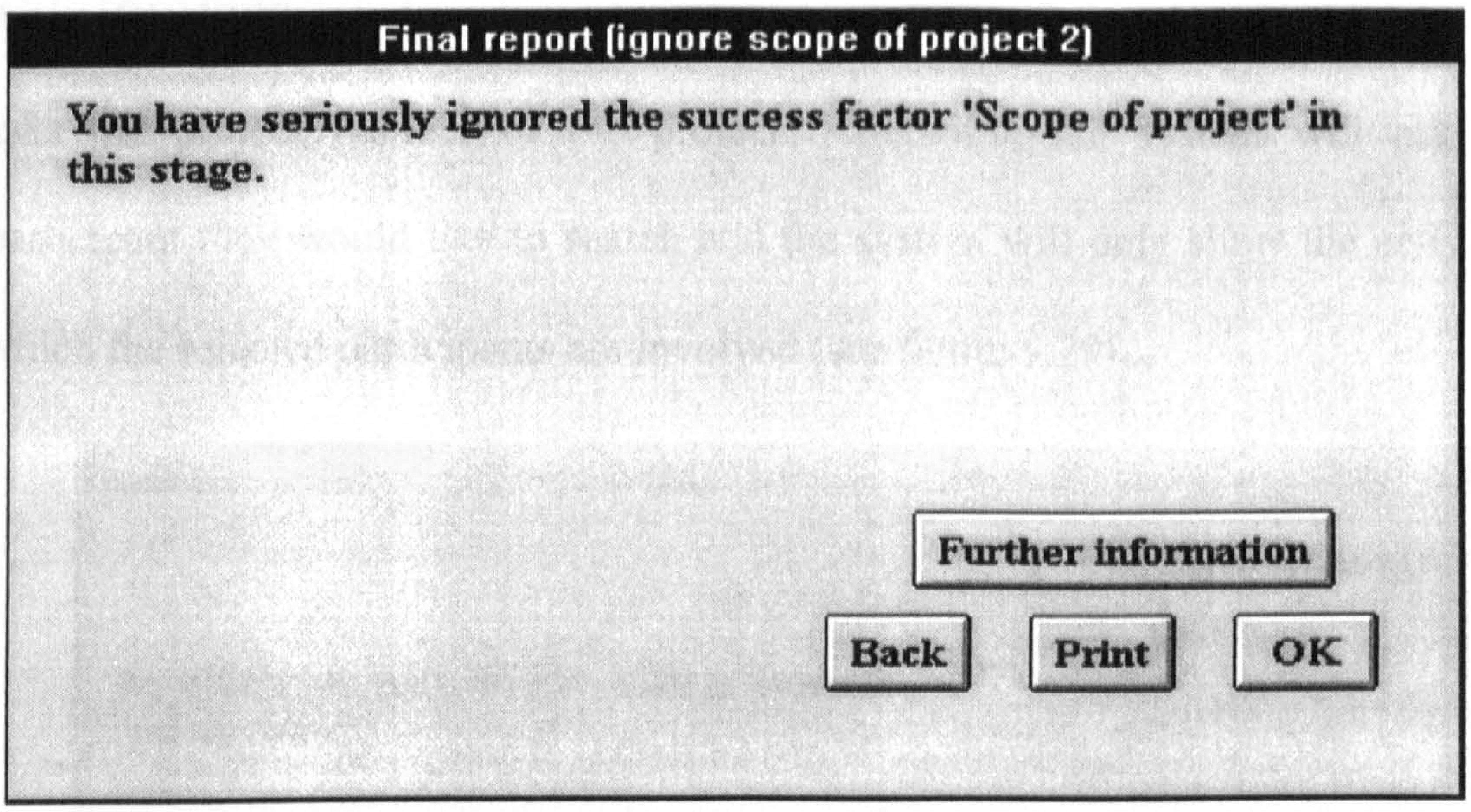


Figure 9.27 Report of the system – ignore success factor 'project team' repetitively

There is also the second level reporting screen of the system. Figure 9.28 is to show the second level report of the success factor 'scope of project'. It will give further information of the consequence of ignoring that success factor. Besides, it will provide the source of further readings on the related topic.

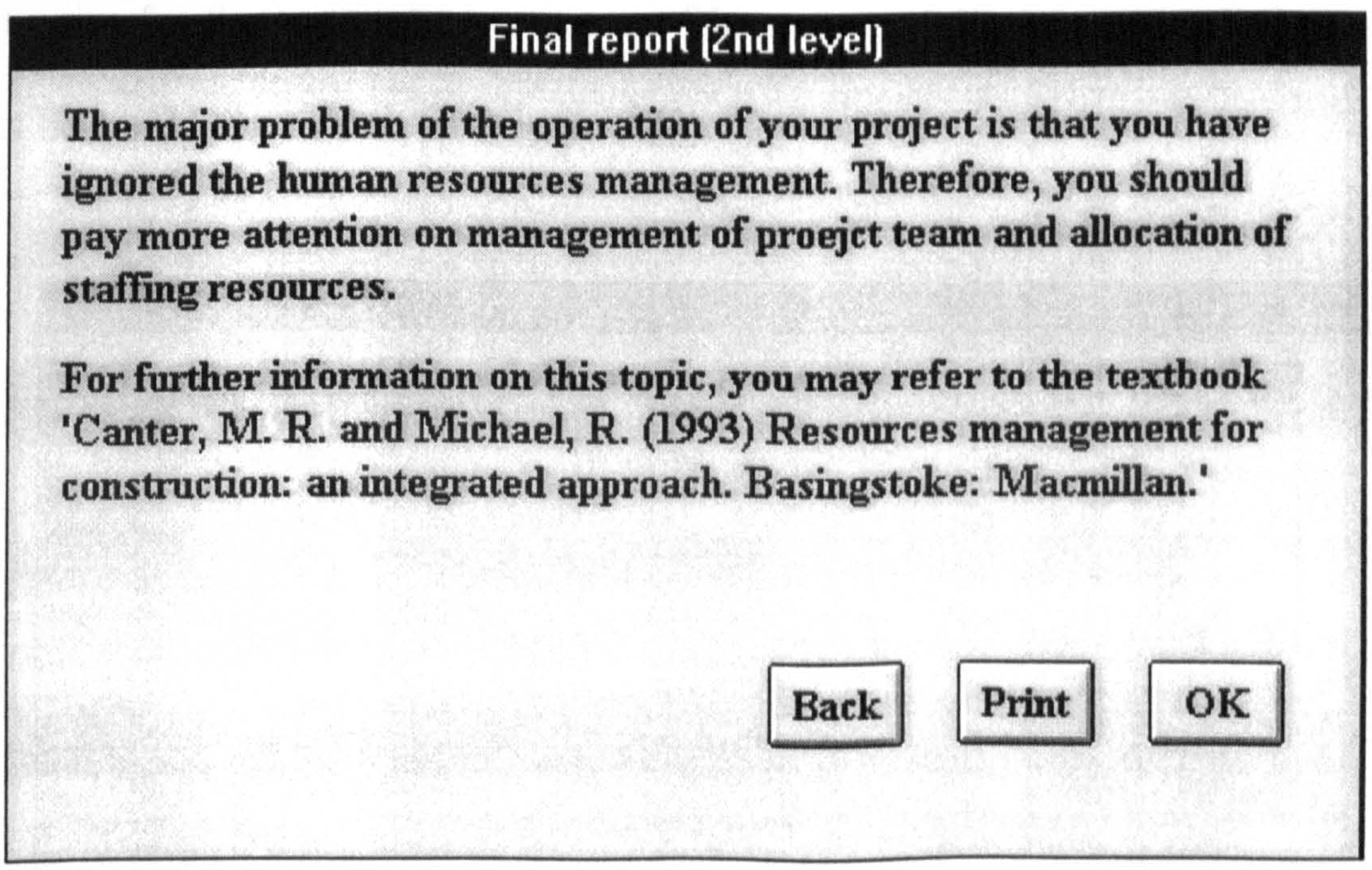


Figure 9.28 Report of the system – second level reporting

We will now consider the operation of the knowledge-based system 'A_All'.

As in 'CONBPS_A', there is the introductory screen at the beginning. Besides, it also asks the project number of the project. Afterward, the system will ask which participant they would like to search and the system will only show the activities in which the selected participants are involved (see figure 9.29).

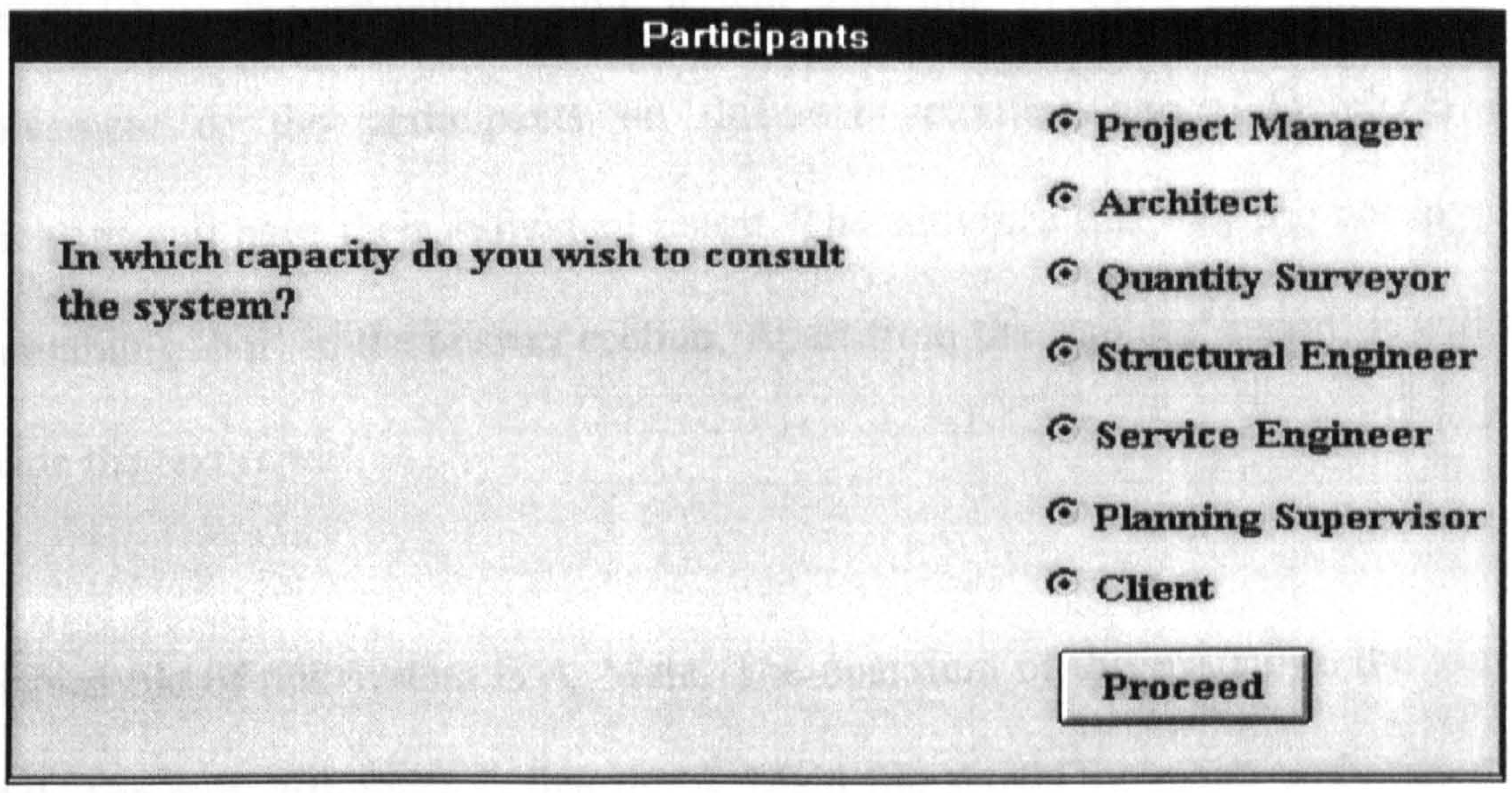


Figure 9.29 Selection of construction participant

After the user selects the construction participant, the screen shows the list of activities for that particular participant. The user can choose any particular activity that he would like to start (see figure 9.30).

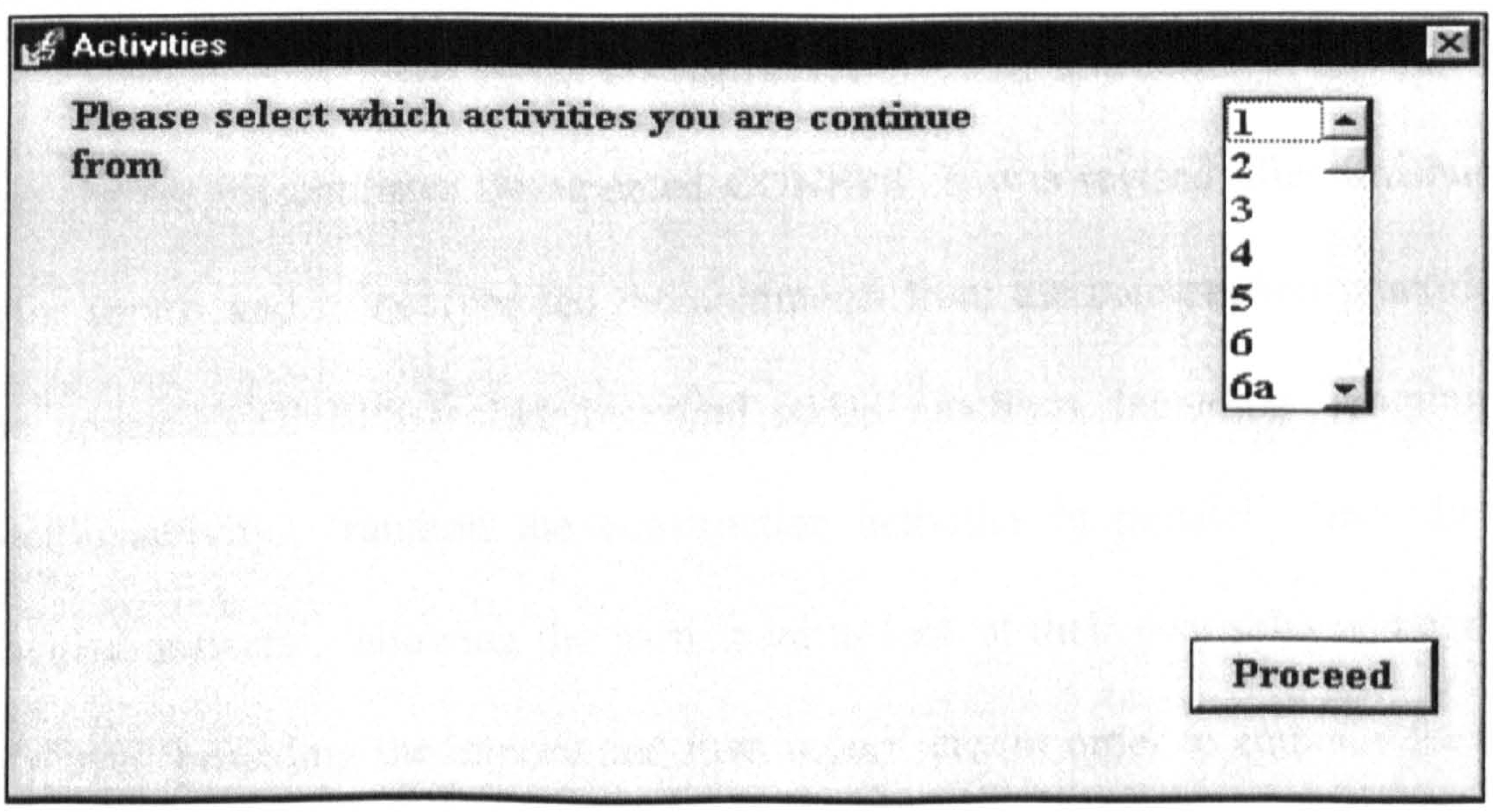


Figure 9.30 Selection of construction activities

After this, the system connects to the activity session. It only shows the activities which the particular participants need to participate in. Similar to CONBPS_A, it will provide an interim report after finishing every four construction activities.

After finishing the activity session, it will also link to show the report. As the involvement of the participants on different activities varies, therefore, each participant will have their individual report. The activities that they are not involved in containing 'Nil' in the answer section. Apart from the 'tabling' report, it will also provide the text report.

The third file of this system is A_Main. The operation of this system is the same as A_All. The only difference is that the A_Main file shows the major activities of the responsible party while the A_All file shows all the activities which are responsible by the responsible party.

9.8 Reflection and conclusion

This chapter disseminates the updated CONBPS. It was revised after finishing the major survey and it incorporated the comments from the construction practitioners. The updated CONBPS included several added functions, including 'jumping to a specific activity', 'running the construction activities in parallel', 'recording the provided answers', 'allowing the participant to look at their own roles and activities only' and 'providing the interim and final report' etc. In order to embrace the above functions, the updated CONBPS has been broken down into three files, which included 'CONBPS_A', 'A_All' and 'A_Main'.

'CONBPS_A' comprises of all the construction activities in the construction stage and lists them in a sequence. 'A_All' comprises of the construction activities with reference to the responsible parties, including major or associated parties, in construction stage A. 'A_Main' performs the same functions as 'A_All' but it concentrates on major parties only.

The final stage of the development of CONBPS is the evaluation stage and it is discussed in chapter 10.

Chapter 10

Evaluation of CONBPS

10.1 Introduction

The purpose of evaluating an expert system is to ensure that the performance of the designed system is problem-free in terms of practical operation or technical structure. There are two methods of evaluating the computer system which are validation and verification and they are the target for testing the performance aspects of an expert system respectively.

10.2 Validation

The validation involves testing the system to ensure it is the right system – that is, it functions as the required specification and meets the experts' expectations. Validation provides assurance that the solutions or advice derived from the knowledge base come close enough to those of the human experts. In other words, the validation process checks the reliability of the expert system. Therefore, it should be tested by the users. Validation should be tested by a black-box approach and ignore the internal mechanics of the system (Awad, 1996; Geissman and Schultz, 1988).

Unlike verification, validation is done only when the system is operational. If the system is modular, each module goes through both steps in evaluating the expert system (Awad, 1996).

10.2.1 Validation of CONBPS

The validation process of CONBPS also has two stages. The first stage is the informal validation of the system by the knowledge engineers. This evaluation process focuses mainly on the performance issues particular to the specification of the system. A number of qualitative validation criteria were chosen in order to provide an independent analysis. The knowledge engineers check whether there is any deviation of actual performance from the predicted performance.

The method for pursuing the first stage validation is to demonstrate the updated CONBPS to the potential users, who are construction participants and get their comments. The aim of this stage of validation is to check the usability and applicability of CONBPS.

The targeted interviewees include all participants who are identified in the updated CONBPS, including project manager, architect, quantity surveyor, client, planning supervisor, structural and services engineers. In order to compare the difference in the comments between the 'new users' and the 'old users', the 'old users' are the same participants who participated in the major stage survey. The aim of choosing this combination is to see whether the 'old users' are satisfied with the updated CONBPS and whether there are any new comments from the new users.

There were some project managers, architects, quantity surveyors, clients and planning supervisors who had participated in the previous stage, one participant from each party was targeted for interview at this stage. The structural engineer and services engineer are the new participants in this project. Sixteen structural engineers and eleven services engineers were targeted. Their names and contact addresses were selected from the following publications:

- (1992) *The GTI Civil & Structural Engineering Journals*, Edition 3.
- (1999) *The GTI Construction & Building Services Journal*, Edition 10.
- Chartered Institution of Building Services Engineers (CIBSE) (1997*) Register of Consultants*. London: CIBSE.

The original information which was sent out to the construction participants is listed in appendix twelve. It includes a covering letter, a reply form and a note describing the enclosed information. This is the updated theoretical framework of CONBPS and it is shown in appendix seven.

The procedure for doing the validation was similar to the method used in the major survey. First, the system was demonstrated and explained, then the author asked the users to comment. Several questions were used to promote a more detailed discussion of the concerned areas. These questions included:

- Is the system the same as what you expected to see (this question for old participants only)?
- What do you think of user interface?
- Are the questions asked by the system comprehensible?
- Does the system identify the critical activities in the construction project process?
- Do you find the explanatory facilities useful?

- Do you have any comments about further development of the system?

Domain experts evaluated the second level of the validation process. The method of pursuing validation was by running a test case. The interviewees at the previous stage worked for different companies, so their understanding of construction process may have been different. This method has an advantage as it can obtain a wide range of opinions on the system. On the other hand, it also has insufficiencies as the comments are probably too broad may loose focus as the experience of the participants varies. It is therefore necessary to include a case study as a complement to the evaluation stage. The chosen project for case study is a construction project which is based on the traditional procurement strategy.

The chosen case study project was a construction project which was designed and managed by the Wolverhampton Borough Council. The background information of the case study is shown in appendix thirteen. The method used for carrying out the second level of validation was also by interview. The author had a discussion with all the participants involved in the case-study project; they commented on the system based on their own experience.

The aspect on which they commented focused on the 'description of the activities' and the 'sequence of the activities'. The related questions that were asked included:

- Did you perform all the activities that have been mentioned in the system?
- Did you follow the same sequence of the activities as advised by the system?

Besides, the participants were also requested to comment on the design of the interface of the system. Moreover, the author also asked the participants to comment on the usefulness of the system as well as the aspects that they considered to be able to be further improved.

10.2.2 Comments from first level validation

Finally, 4 structural engineers and 4 services engineers were willing to be interviewed, the response rate was 30%. Thirteen participants were involved in the evaluation process, including five old participants and eight new participants. Table 10.1 lists the position of the respondents.

Table 10.1 Position of respondents

Position of respondent	Number
Director *	3
Partner +	2
Quality System Officer #	1
Head of Property Services (Business Unit) #	1
Associate	1
Technical Director Building Services	1
Regional Design and Build Manager	1
Regional Director	1
Principal Structural Engineer	1
Consultant	1

* Two are old participants
\+ One is old participant
\# Old participant

In order to ensure that the new participants had enough experience to comment on the system, some background information was asked. The description of their experience is stated in table 10.2.

Table 10.2 Experience of interviewees

Respondent	Background	Experience with traditional procurement
ST_1	His background is a structural engineer and has 16 years experience. He joined the current company in 1998 and he worked as a structural engineer at the beginning. Recently, he moved to a specific section of that company, which focuses on the development of a process modelling and mapping.	He has experience in all forms of procurement strategy, which includes traditional procurement strategy, design and build etc. Also, the projects that he mainly participates in are new building projects. He has considerably less experience in road and civil engineering construction work.
ST_2	He worked as a structural engineer for 25 years.	In the last 10 years, he focused on the management aspect of construction management. His experience of traditional procurement strategy is dated back to the early experience.
ST_3	He is a structural engineer. He retired last November and he works as a part-time consultant in the company now.	About 40 years experience. Most of the time he worked with traditional procurement strategy.
ST_4	He worked as a structural engineer for 20 years.	Entire 20 year experience
SE_1	His background is an electrician. He studied electrical services engineering university. He joined this company 13 years ago. Now, he works as an electrical services engineer and he is an associate in this company.	All of his 13 years experience in this company was with traditional procurement strategy.
SE_2	He is a mechanical service engineer. Also, he worked as a building services consultant, and a partner of the company.	18 years experience in traditional procurement strategy.

Respondent	Background	Experience with traditional procurement
SE_3	His background is building services is that he took a diploma course in environmental engineering. Afterwards, he worked for a contractor. Later on, he joined the current company to work as a structural engineer.	Total 35 years experience.
SE_4	He is a mechanical engineer by training. He started work as a mechanical, electrical specialist and did this for 9 years. Afterwards, he worked as a lecturer at Loughborough University for three years. He has worked in the current company as mechanical engineer for the last 20 years.	He spent the last 30 years in various procurement strategies, from both the contract side and from the consultant side. He participated in preparing specification and contracting documentation etc.

All the old participants appreciated that there was a considerable development of the updated system. Most of them agreed that the updated system included the comments that they made previously. Besides, the respondents appreciated the idea of developing the system which listed the roles and responsibilities of all the construction participants, so that they can have more understanding of when they need to be involved and with whom they need to co-operate with. Also, the respondents agreed that it is a good guidance for new participants in the construction industry as it attempts to include different critical aspect of the construction project in a single system.

The following sections are the discussion of the practitioners' comments on the system.

With regards to the system interface, the most common comment concerned 'consideration of time'. The respondents commented that there is the necessity for linking the construction activities to the time schedule. It is a good idea to inform the user how far the project has gone and how much time is remaining from the targeted finishing point. Also, they suggest that it is better to list the construction activities in a traditional method, like bar chart instead of identifying them in numbering.

Besides, the participants advised to put the system in a location that could be assessed by the users easily, for example, put it on the web. If the system has been put on the web, they can access and update the system in their own office. Also, they can view the progress of the project.

Furthermore, the participants suggested that the theoretical framework should be included in the system. Currently, users can only view the description of the construction when they arrive at that particular stage, the interviewees found that this is not always convenient. The aim of adding the theoretical framework into the system is to allow the users to view all the activities in the current construction stages.

The new participants advised that the system should add the function of the role of construction participants and activities. The involvement of the participants in a construction project depends on the project nature. For example, a simple project may not employ a project manager and the architect will act dual role - as designer and manager of the project. On the other hand, some complex projects may need to employ the specialists for performing some specialist functions. As the activities are linked to a number of construction participants, therefore, it was advised to add the function of construction activities.

One structural engineer gave some further comments. He advised that apart from viewing the information on the computer, it should also let the user print the hardcopy of the construction process as this is a more convenient reference.

On the aspect of the comprehension of the construction activities, two participants have mentioned that it is necessary to breakdown the activities into several hierarchical levels. Although the author has already included this idea in the updated system, they think it should go further in this aspect.

With regard to the issue of the critical activities in the construction project process, one structural engineer mentioned that it depended on one's own point of view, because different parties have a different emphasis. Overall, all participants agreed that time, cost, quality and safety are the critical issues for the construction process.

The users were highly appreciative of the explanatory facilities and the function of linking to 'additional information' as they considered it the most useful part of the system. Also, they advised on several aspects in order to enhance the usefulness of this function. First, they advised that it should be able to link to the web-site of the professional institutions. It is the fastest and the most convenient way for the users to search for the updated information about their professions. The second aspect is to include the list of the activities into the system as it provides a more complete picture on the whole process of the construction stage.

The interviewees also made some recommendations for future development. Several participants recommended that there should be an expansion of the current system to other construction stages and other procurement strategies. One services engineer suggested developing the modules which group different activities under different critical criteria. This is because different users may have different concerns on the critical criteria and this arrangement was convenient for them.

After receiving the comments from the practitioners at the first stage validation, the system was re-updated before starting the second stage of validation and verification. The final version of CONBPS has incorporated most of the comments and it is discussed in section 10.4. However, some comments have not been incorporated because of various reasons and they are further explained in the following paragraphs.

The first unincorporated comment is 'consideration of time'. The actual and the proportion of time spending on the construction activities are various. It depends on the size and nature of the project etc. The aim of this system is to be a general advice model, and providing advice on the sequence of the activities is enough for this project. It is not appropriate to consider the 'timing' issue as it will constrain its usability.

The second comment is the function of 'adding activities and specialist consultants'. The identified parties are the 'common' participants in construction projects. Again, it follows the theorem of 'generality' of this system.

The third comment is related to 'further break down of the activities'. The author has already included this concept in the first edition of the updated system. It is a subjective judgement on how many hierarchical levels need to be considered. Instead of breaking into too many hierarchical levels and making the system more complicated, the author considers that it is better to stick to one level.

The fourth comment is to put the system in a location that could be accessed by the users easily, for example, put it on the web. It needs an affiliated software called 'Thin Client' and it is beyond the financial limitation of this PhD project.

The final comment is to 'expand this concept to other procurement strategies'. The author focuses on the traditional procurement strategy because (1) it is the procurement strategy which is subject to most criticism and (2) limitation of time and resources. The author intends to develop the idea on a particular procurement strategy. After proving and ensuring this idea is useful and applicable, it may be expanded to other procurement strategies in future research.

10.2.3 Comments from second level validation

The case study project related to the building of an individual technology block for Pendeford High School. The duration of this project was from December 1994 to February 1998. The consultants for this project included an in-house architect, a quantity surveyor, an electrical service engineer and a mechanical services engineer, all from Wolverhampton Borough Council. In addition, there was an external structural engineer. There was no individual project manager and planning supervisor for this project as it was a small-sized project. The architect acted in the dual role as project manager and designer for this project.

The clients of this project included the primary client, who was the Education Department of Wolverhampton Borough Council and the secondary client, who was Pendeford High School.

The author interviewed all the participants identified in the CONBPS system and requested them to comment on the system based on their experience of constructing Pendeford High School Technology Block.

The first question asked the participants whether they had finished all the activities mentioned in the system. Basically, they did all the activities that were mentioned in the system, but they did not go into such great detail. This is because the case study project is a small project, with a value of only £650K. Besides, most of the consultants were in-house consultants and they had a well-established a working relationship and could thus avoid many of the procedural activities. For example, they did not need to produce an extensive list of legal activities. Moreover, they were able to ask for the information on project budget before the formal appointment of consultants. Also, they provided informal advice to the client at the inception stage.

The interviewees also made comments on the responsibility of participants. They mentioned that there is no project manager for this project, as the architect acted in dual role as project manager and designer. Furthermore, the level of involvement of the client is higher than mentioned in the system. It is probably due to the fact that the client is an experienced client, i.e. the Education Department.

The second question asked the participants whether they followed the same sequence of activities as advised by the system. The interviewees commented that they do not exactly follow the same sequence as advised by the system. Again, it is due to the fact that it is a local authority construction project and most of the participants are in-house consultants and they have a close working relationship.

The first difference between the case study project and the recommendation of CONBPS is the involvement of certain consultants. The mechanical services engineer and electrical services engineer were involved earlier than the system advised. This was because this project is not a stand-alone project, it is an extension of an existing development and the services engineers needed to check whether the existing services could support the extended work. In other words, the specialist designers needed to be involved earlier than what is usual practice.

Furthermore, they do not prepare the consolidated scheme with detailed cost information at so early in the project cycle as advised by the system. This is because the client, the Education Department, needs to obtain the approval of funding before signing the official document. In other words, the consultants obtained formal client approval at a later time during the inception stage.

Besides, instead of asking the client to provide the brief to them, the consultants contacted the client and asked them what they wanted. In other words, they helped the client to prepare the brief.

The third question asked the users to comment on the design of the interface of the system. Generally, the users appreciated that it is a user-friendly computer system. Also, it is a good checklist lists all the construction activities in great detail. However, they also made a comment that the system more likely applies to large projects as it discusses the construction activities in great detail.

Finally, the author asked the participants to comment on the possible areas of future development. The consultants commented that the system should breakdown to several levels and give different levels of advice depending on project size. For example, if the cost of project is over £1 million, it should go to level 3 advice, which is the high advice level. If the cost of project is between £500,000 to £1 million, it should go to level 2-advice etc.

However, this comment may be difficult to consider as one of the future research areas, it is because it is difficult to 'identify' what activities need to be done simply depending on the size of project.

Overall, the practitioners agree that they have principally done all the activities that are mentioned in the system and in the sequence as advised. The deviation between the actual procedure of the case study project and the advised procedure in the system are due to the 'nature' of this project. This is a local authority project and most of the

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10.3.1 Verification of CONBPS

There is a two-level process to carry out verification of CONBPS. The first level is at micro level. The accuracy, appropriateness and clearness of each activity will be checked. Besides, the accuracy of the sequence will also be checked. The second level is at macro level, which is used to check the consistency of each module. The contents of the activity in the system are checked and verified for any discrepancies and errors against expected outcome and human experience. This was achieved by the submission of the developed system to the experts in expert systems for criticism and evaluation. Their comments and suggestions were incorporated into the system wherever this was possible.

The method used to carry out the micro-level verification was to run the system by the author so as to check the discrepancy between the expected outcome and the predicted outcome. The author prepared the checklist which stated the predicted outcome and the actual outcome of each possible combination. Based on this checklist, the author should be able to detect any discrepancy between the actual and the expected outcome.

The method used to carry out the macro-level verification was by submission of the knowledge-based systems of the updated CONBPS to an expert in developing expert system. The targeted person is a Principal Lecturer in the School of Computing and Information Technology (SCIT) within the same university.

10.3.2 Comments from micro-level verification

The author ran the whole system and checked if there were any discrepancies between the expected outcome and the real outcome. Four checklists were prepared to check the four knowledge-based systems 'Introduction', 'CONBPS_A', 'A_All' and 'A_Main'. The verification checklists are shown in appendix fourteen to appendix seventeen.

The checklist reflected that the developed system operated as it was supposed to, and there was no variation between the actual and expected outcomes.

10.3.3 Comments from macro-level verification

Before the macro-level verification process started, the author briefly explained the structure of the system, its operation and its expected outcome. Afterwards, the lecturer in the School of Computing and Information Technology (SCIT) ran the whole system and checked if there were any errors, discrepancies or insufficiencies against his experience and expected outcome.

Basically, the SCIT lecturer was satisfied with the design and structure of the system; it also achieved the expected outcome. However, the lecturer made three comments.

The first comment was related to the content of the 'interim report'. The current interim report has identified the related success factors for the whole section even though the user has provided only one invalid answer, that means answering 'no' for one activity only. The SCIT lecturer commented that the system should report the recommendation for the related invalid answer only. For example, if the user answer 'no' to activity one, the system should only provide recommendation that are related to activity one only.

His recommendation was the original development idea of the author. The author agrees that providing the only related recommendation to the invalid answer is more preferable. However, providing these functions in a system developed by XpertRule is very highly complicated. This would easily cause clashes with other functions of the system. Therefore, the author has designed the one report for each section as it is a more convenient and reliable method for providing the same purpose.

The second comment related to the 'audit-trial process' of the system. The developed system can record the 'status' of the activities that is whether it is 'finished' 'in processing' or 'not yet finished'. However, it cannot record which participant provides the answer. The SCIT lecturer has commented that the system should record 'who' provided the answer. His advised amendment was to provide the 'user code' for each participant and they should type it at the beginning of the system; this is aimed at identifying who provides the answer for each activity.

For the knowledge-based system CONBPS, all participants can provide answers to all activities. For A_All and A_Main, only the related party can provide the answers to the activities. The other participants can only view the answer and check the processing status of the project, but they cannot amend or provide the answers for the activities.

This function is simply concerned with the 'security aspect'. It is concerned with checking who provided the answer and the other participant can chase back the information if necessary; this is not related to the development of the knowledge base.

The final comment related to the 'continuous activities'. The author identified several activities as continuous activities and mentioned the starting time for these activities. The SCIT lecturer commented that it should mention the completion time. Although it may be difficult to provide an exact timing of when a particular activity is finished, it should still provide the advised time. For example, that continuous activity should be finished before the start of which activity. This is because there should be the finished time for all activities, even though they are continuous activities.

10.4 Final version of CONBPS

There was no dramatic alteration in the final version CONBPS. In order to incorporate the comments from validation and verification, some functions have been added and the operating structure was modified.

10.4.1 Added functions

The added functions into the final version of CONBPS included:

- Connect the system to other software, for example, MS Word and Internet Explorer. This is to enable the user to retrieve the information, for example, theoretical framework and standard application form which need to be put in other software. Also, the user can access the Internet in order to retrieve the most updated information
- Add the help function of the system
- Provide the 'user code' for each participant, this is in order to identify who gave the answer for each activity.

10.4.2 Operating structure

This section is aimed at discussing the operating structure of the final version of CONBPS. In order to avoid the replication of the presentation of the system, this section will only discuss the added functions.

Figure 10.1 shows the introductory screen of the final version of CONBPS. If the users choose the icon 'Theoretical Framework', it connects to a Word file which shows the 'Theoretical Framework' of CONBPS. If the users choose the icon 'Help', it links to the 'on-line help' screen of the system.

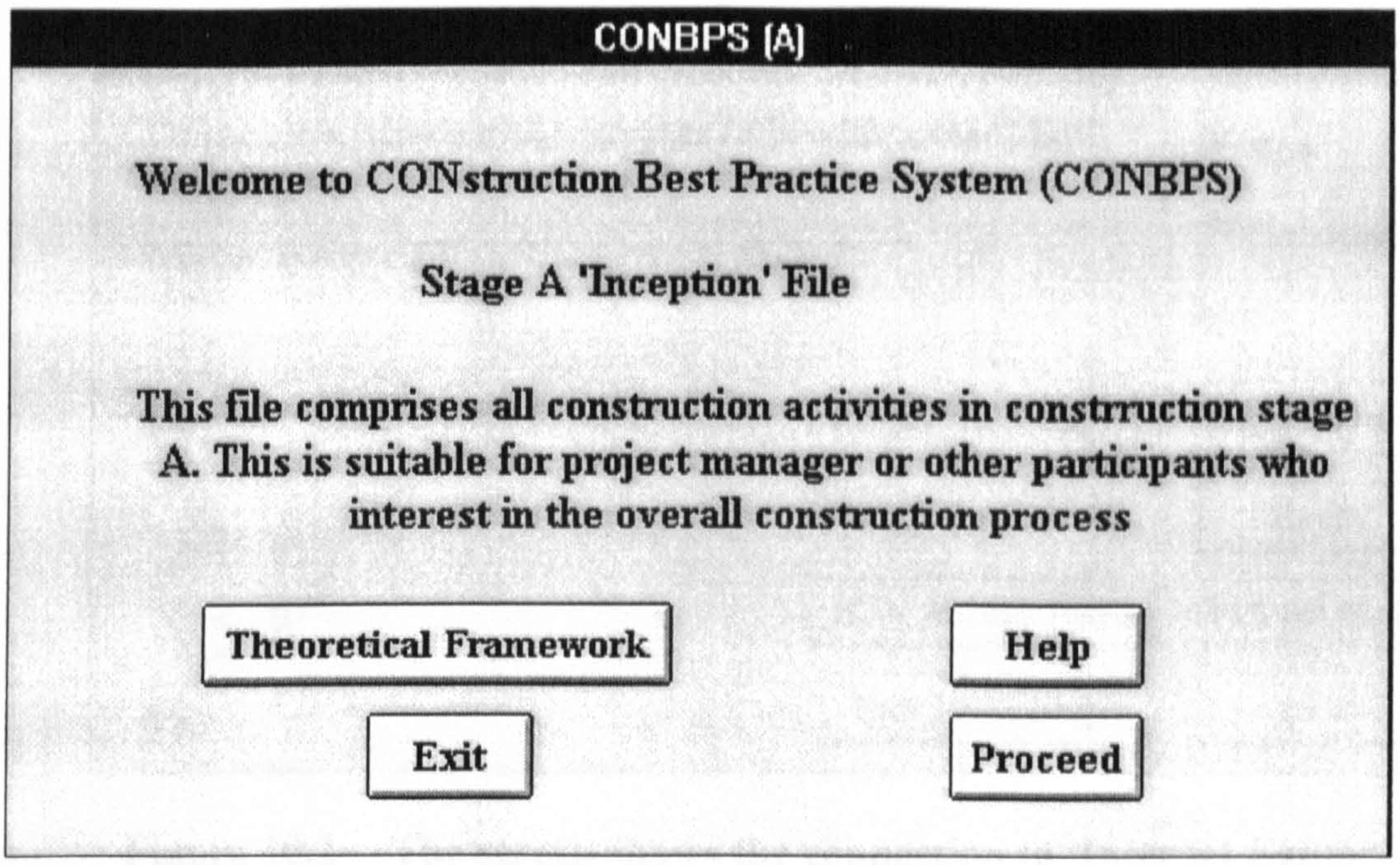


Figure 10.1 The screen shows the connection to 'MS Word' and 'On-line Help'

Figure 10.2 is the sampling screen which shows the function of connecting to 'Internet Explorer'. This activity is related to CDM Regulation and it connects to the Health and Safety Executive (HSE) Home Page in order to facilitate the user to retrieve the updated information on health and safety. The user can connect to the HSE website by simply pressing the related icon.

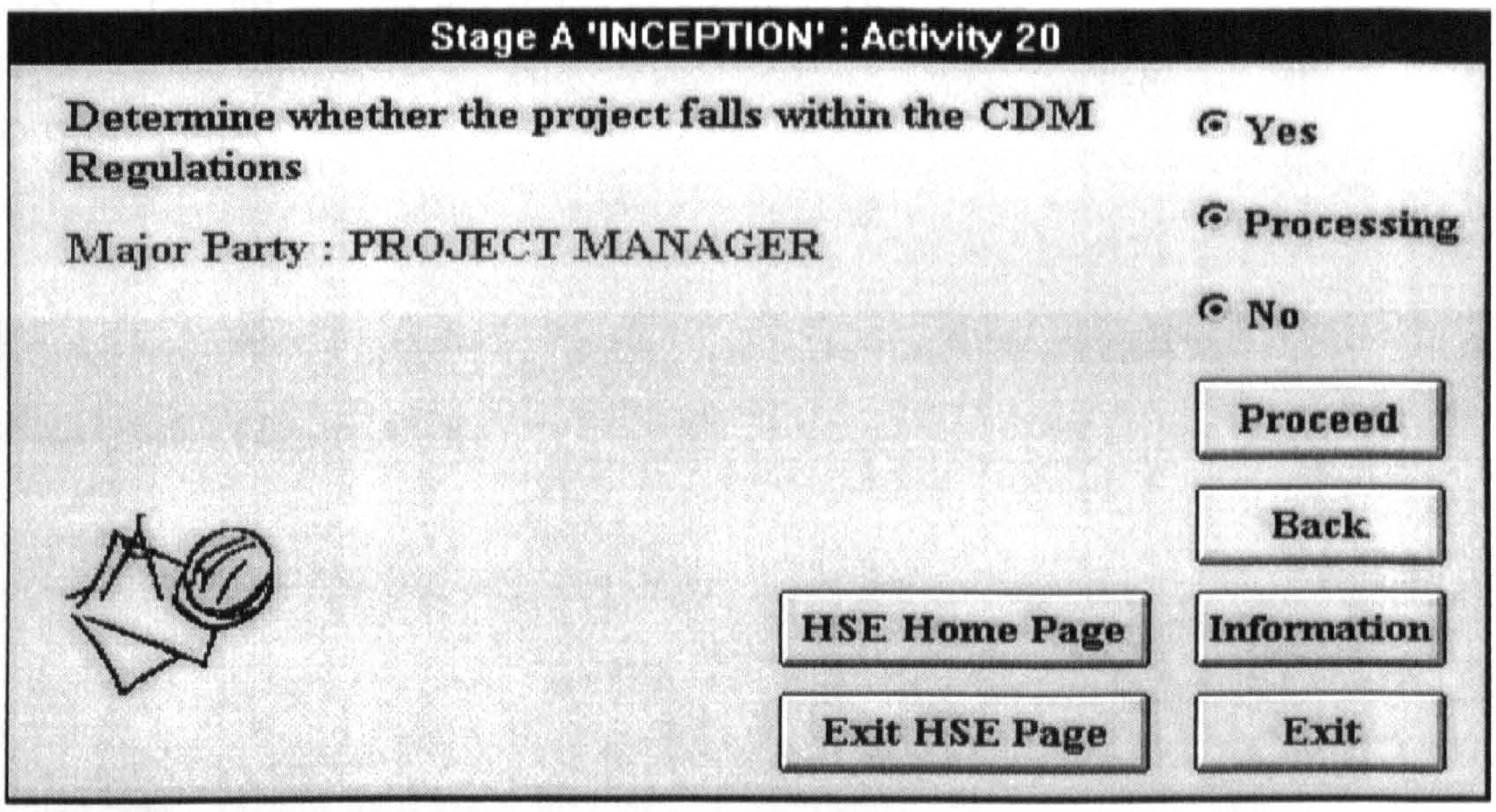


Figure 10.2 The screen shows the connection to 'Internet Explorer'

Figure 10.3 is the decision tree of the final version of 'A_All'. There is an added procedure 'User_PM_Proc'. The aim of this procedure is to identify who provides the answer for each activity and this information will be shown in the final report.

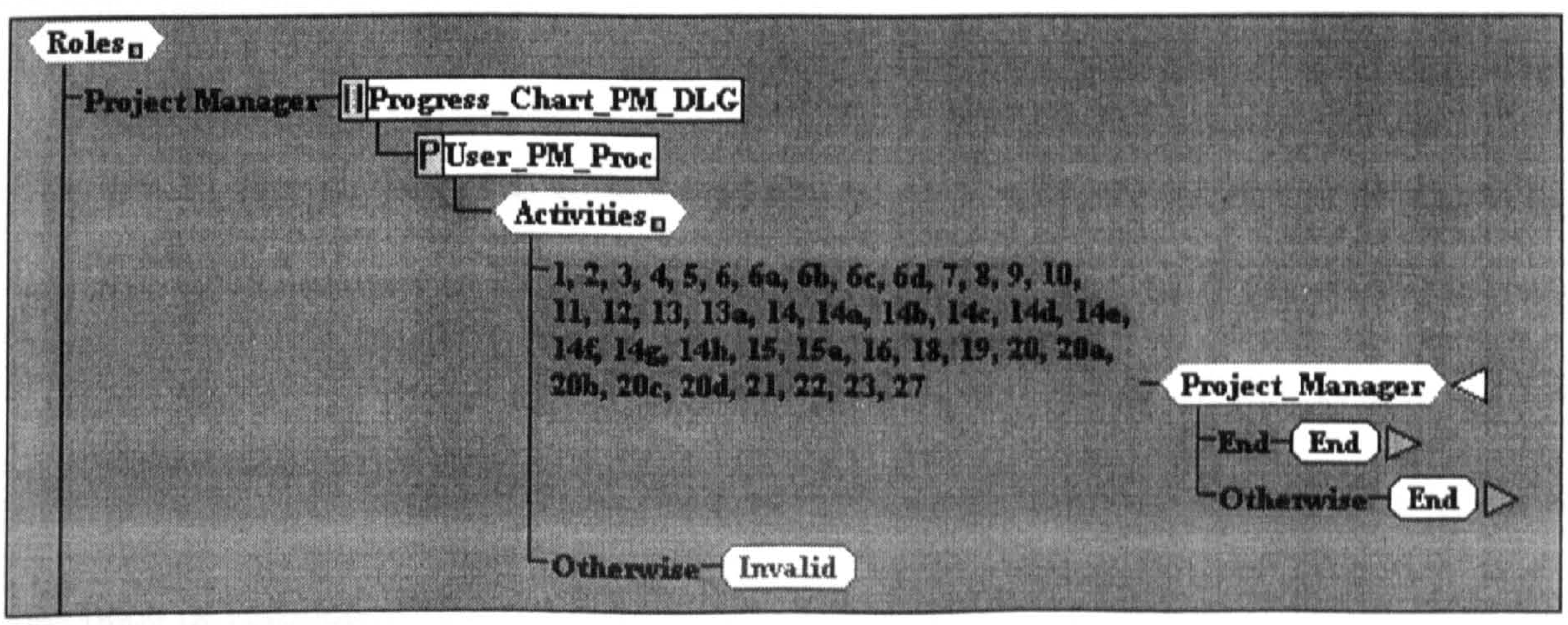
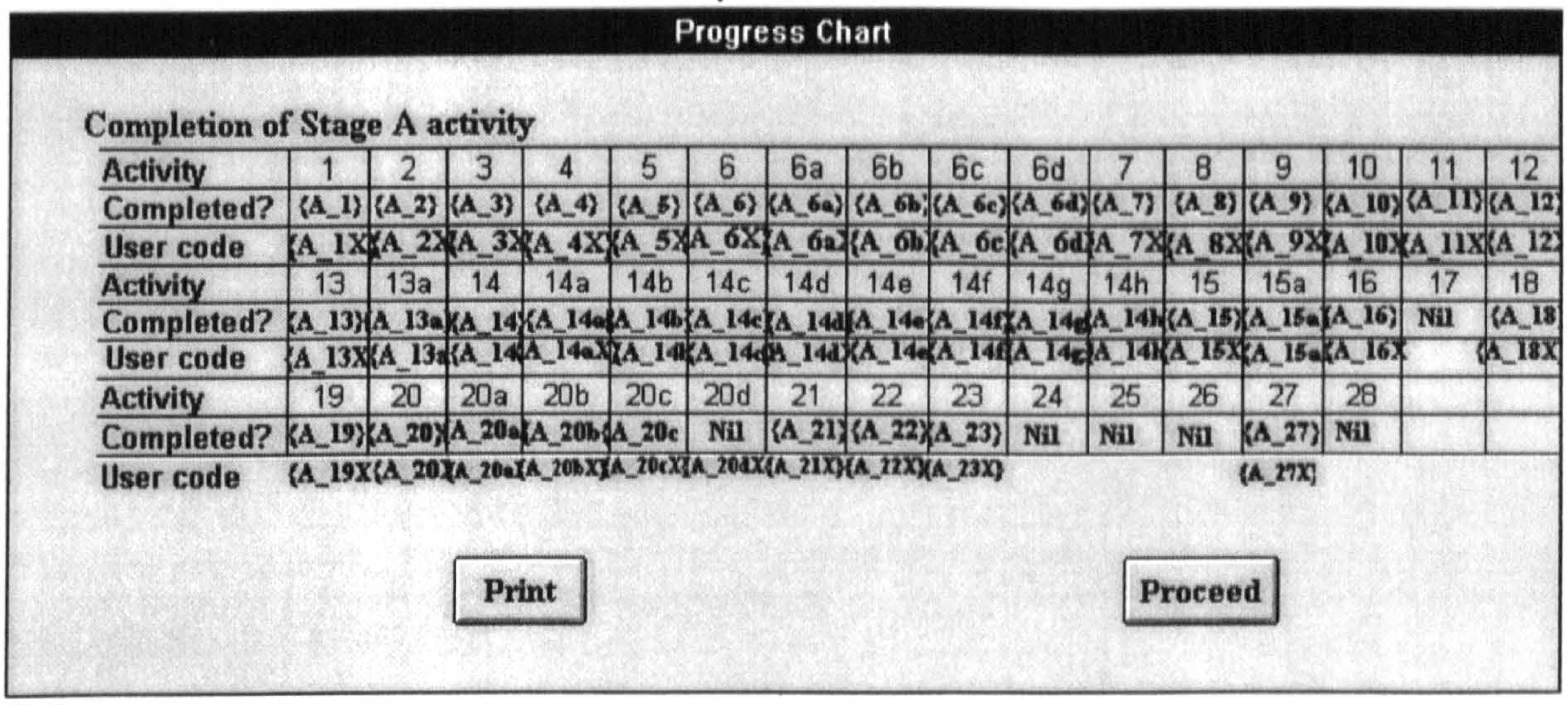


Figure 10.3 The decision tree provides 'user code' of participant

Figure 10.4 is the report of the final version of CONBPS. Apart from stating the answer for each activity, it also lists which participant is providing the answer. Similar to the previous version, the row 'Activity' lists the number of activities. The row 'Completed?' reports the status of answer. The 'User code' row shows who is the responsible party.



Progress Chart

Completion of Stage A activity

Activity	1	2	3	4	5	6	6a	6b	6c	6d	7	8	9	10	11	12
Completed?	{A_1}	{A_2}	{A_3}	{A_4}	{A_5}	{A_6}	{A_6a}	{A_6b}	{A_6c}	{A_6d}	{A_7}	{A_8}	{A_9}	{A_10}	{A_11}	{A_12}
User code	{A_1X	{A_2X	{A_3X	{A_4X	{A_5X	{A_6X	{A_6a	{A_6b	{A_6c	{A_6d	{A_7X	{A_8X	{A_9X	{A_10X	{A_11X	{A_12X
Activity	13	13a	14	14a	14b	14c	14d	14e	14f	14g	14h	15	15a	16	17	18
Completed?	{A_13}	{A_13a	{A_14}	{A_14a	{A_14b	{A_14c	{A_14d	{A_14e	{A_14f	{A_14g	{A_14h	{A_15}	{A_15a	{A_16}	Nil	{A_18
User code	{A_13X	{A_13a	{A_14	{A_14aX	{A_14	{A_14c	{A_14d	{A_14e	{A_14f	{A_14g	{A_14	{A_15X	{A_15a	{A_16X		{A_18X
Activity	19	20	20a	20b	20c	20d	21	22	23	24	25	26	27	28		
Completed?	{A_19}	{A_20}	{A_20a	{A_20b	{A_20c	Nil	{A_21}	{A_22}	{A_23}	Nil	Nil	Nil	{A_27}	Nil		
User code	{A_19X	{A_20X	{A_20a	{A_20bX	{A_20cX	{A_20dX	{A_21X	{A_22X	{A_23X				{A_27X			

Print

Proceed

Figure 10.4 The report shows 'user code' of participant

10.5 Reflection and conclusion

The aim of this chapter was to evaluate the CONBPS system. The evaluation stage consists of two methods, which included validation and verification. These two methods focus on the interface and technical performance of the system. After incorporating the comments from the evaluation stage, the final version of CONBPS has been developed.

Chapter 11

Conclusion and recommendations

11.1 Conclusion

This thesis has set out the development of CONstruction Best Practice System (CONBPS). It is an expert system, which lists the sequence of the construction activities and the responsibilities of the parties.

The system should provide the above information via interim reports. Additionally at the end of the project the system should provide a report explaining which tasks have been skipped and the possible consequences.

Expert system tools have great potential in solving ill-structured problems commonly encountered in construction. CONBPS is capable of transforming ill defined and piece-meal knowledge about construction activity and other related information into an operational prototype system. The advice provided is not committed to a single project or case, but is considered at conceptual level. Therefore, it can be applied to a wide variety of construction projects. The costs of consultation with experts can also be limited with such an expert system and time could be saved in waiting for the expert to arrive on site. Additionally, although textbooks can provide an important and valuable source of information, having on-line advice from a real expert is more practical and user-friendly.

Before the discussion of the development of CONBPS started, there was a discussion on the previous construction process models. These models were classified according to their characteristics and the methods that they adopted.

This was followed by a description of the theoretical development of CONBPS; the framework has three columns: 'criteria', 'participants' and 'activities'. Although the well-known RIBA Plan of Work was used as the skeleton of this framework, CONBPS contains additional information which has been abstracted from various sources in order to reflect modern construction management issues.

This framework was sent out to practitioners for comment; the targeted respondent being the Housing Associations within the UK. The comments received were not very critical. It may be due to the fact that they did not receive so much information. The responded Housing Associations were divided into four groups, and each group received the framework of three RIBA construction stages. The main comments made by them included 'increased involvement of the client', 'increased involvement of the planning supervisor' and 'procurement process for private sector is easier'.

The comments from the representatives of the Housing Associations were then incorporated into a revised system. Based on the literature and the comments, the prototype of CONBPS was developed. CONBPS is an expert system which is designed for project managers, client representatives or any practitioners in the construction industry who use traditional procurement strategy. This system has modelled the construction activities and has an explanatory facility built in the system which can provide additional information.

The method used to obtain comments on the prototype was by interview. The targeted interviewees included the participants who were identified in the CONBPS prototype. They included architects, quantity surveyors, clients and planning supervisors. As

CONBPS focuses on modelling the construction activities in the concept design stage, there was no role for the contractor. Practitioners' comments focused on: 'criteria', 'roles of parties', 'sequence of work', 'description of activities', 'omitted activities' and 'user interface'.

Following comments from the practitioners, CONBPS has been updated. Both the theoretical framework and the system interface have been updated. The first amendment on the theoretical framework concerned the roles of the parties. Apart from the major party for the activities, the participants who should provide support were also identified in the framework. The second amendment related to the activities. Certain activities were classified in a hierarchy. Some activities, like cost management were a major section with sub-headings, including cost control, cost advice and cost estimates etc.

On the 'interface' front, more functions were added. These functions included 'go back to the previous activity', 'running the construction activities in parallel', 'jump to specific activity', 'allowing the system to continue even if the user has not finished the previous activity', 'record the previous answers', 'allowing the participant to look at their own roles and activities only' and 'give interim report during the construction stage and final report at the end of each construction stage' etc. The aim of adding these functions was to facilitate the user and let the user learn from the experience on the past projects.

The updated CONBPS has also been evaluated. The evaluation consists of two stages: validation and verification. Validation aims at testing the system to ensure it is the right system and verification aims at checking 'is the building of the system right'. In other words, validation aims at checking the practical aspect of the system and verification aims at checking the technical aspect of the system. Consequently, the final version of CONBPS has been thoroughly developed.

11.2 Advantages of CONBPS

CONBPS has clearly identified the roles and responsibilities of the major parties of the building team and identified the issues within the project cycle which can prove critical to project success. The use of CONBPS is beneficial in both practical and academic terms.

From the practical point of view, various construction participants can use this model. Firstly, the project manager can consult the system to check the sequence of work and the responsible parties for each activity. Before finishing one activity, they will know what they should do and who is the responsible party for the next activity; therefore they can better plan the project cycle before execution.

For the construction parties, they can consult the system to check when is their activity and what should they do. They can also check who is the respondent for the previous activity and the next activity, so they can communicate with them if necessary. Moreover, there is 'Additional Information' for each activity. The responsible party can refer to the information if they have some queries on the construction process.

For the arbitrators or the person who need to sort out the claims issues in the construction projects, they can consult the system on an ad hoc basis. They can use this system to counter-check whether the project has followed the advised construction procedure.

From an academic point of view, CONBPS can be used as an aid of teaching for the subjects such as construction management and project planning. As CONBPS identifies the construction activities in a sequence, providing additional information for each activity, the learner or students can become familiar with the whole construction process by studying a single model. Also, they can understand the role and responsibilities of individual participants by viewing the same model. Furthermore, the presentation of this by an expert system provides a user-friendly interface to the user.

Apart from these, certain functions benefit all individual types of participants. First is the identification of the criteria for each activity. The user will know what is the impact on time, cost, quality or safety if they don't finish that particular activity. Besides, the system will provide the reminder list indicating what activities should be completed in the short term. Therefore, both the project manager and the related parties can do some preparation for these activities. Furthermore, the system will also give an interim report throughout the construction process and a final report at the end of each construction stage. The users can learn from experience so as to improve the future projects. The system can therefore be used to improve the efficiency of the design and construction process.

The design of this system is focused on the causes of inefficiency in the construction industry. Moreover, it concentrates on the traditional procurement strategy, the procurement strategy that is subject to the most criticism.

In the following section, the benefits of the system will be discussed in more detail. It is divided into two sections: the design of the system and the presentation of the system.

The RIBA Plan of Work (RIBA, 1995) has been chosen as a skeleton framework. Besides, modern construction management issues, such as risk management, value management, total quality management, safety management, design management, environmental management, partnering, benchmarking and constructability, have been included in the system (Poon, et. al., 1999). The user can easily use the system as it follows the well-known classification of building works. However, the changes within the construction industry have been greater in the last five years than the past fifty years. Although the RIBA Plan of Work published the updated version in 1995, it still does not embrace all the post Latham issues. The advantage of this system is that it includes all these issues.

CONBPS has converted the information from the RIBA Plan of Work and the modern construction literature into the sequence of activities. Apart from listing the sequence of activities, the responsible participants and parties have also been identified. Moreover, the success criteria of each activity is stated. The advantage of this arrangement is that the user knows when they should participate, what they should do and what the impact will be if they don't finish their activity. It pinpoints the reason for inefficient construction. Besides, the system provides 'Additional Information' for the activity and can therefore help inexperienced construction participants when they are managing the construction project.

Apart from the design, the presentation of the system also has advantages. The method for presentation of this model is via an expert system. An expert system attempts to model the intelligent reasoning and the problem-solving capability of the domain experts. It is capable of transferring expert knowledge about the construction process to less experienced personnel. This appears to be a useful area of expert system development because the continued evolution of portable computers will allow professionals to use these programs in the field. Besides, it is an interactive program, which contains expert knowledge. It can also be used on the construction site which has the potential to improve the quality of construction.

The software for developing CONBPS also has its advantages. XpertRule was used as the software for developing this system. It is a decision tree based environment. This environment is good for prototype development as the whole structure is shown in a 'map' and it can be viewed easily. It is very easy for practitioners to view the whole structure of the system, therefore, it is more convenient for them to make comments as they can view the structure easily.

For the construction process, the primarily benefit of this system is the dissemination to the participants or inexperienced professionals of advice on the sequence of construction process, factors for construction process, guidance on what they should do in the short-term and additional information etc. Therefore, it is the quicker recognition of these issues and earlier preparation.

On the economic front, CONBPS also has its advantage. The system can run on comparatively low cost hardware (PCs) and will stand alone, which will make the technology particularly useful to small companies. Besides, as the interface of the system is simple and user-friendly, the user will not need to be a computing expert.

In summary, the benefits of CONBPS include

1. 'Focus' and the 'detail' - It focuses on a particular procurement strategy, it lists the construction activities in detail and identifies the relevant parties. Additionally, it also provides information on the activities.
2. Practicability – It uses the well-known RIBA Plan of work as the framework, so the operations are easier to follow. The design of the interface is user-friendly.

11.3 Contributions of CONBPS

This research contributes a novel step forward in the development of an expert system in the construction process model domain. The work has demonstrated that the development approach is broadly sound, and that there is a list of construction activity and information section, which can be applied to generate project tasks and to assess the efficiency of construction process. It represents a modest contribution to the improvement of the construction procedures.

The research has led to certain level of advances in construction process modelling through several distinct ways.

Firstly, it converts artificial intelligence tools capable of transforming ill-defined and piece-meal information of construction activities and its related information associated with them, into an operational expert system.

The second important advance of this study is through the synthesis of construction activities and their responsible participants that enable the project manager to manage the project. The sequence of construction activities represented in this system are not committed to a single project or case, as they are considered conceptual in nature. Therefore, it can be applied to the great majority of construction projects. In this way, the synthesised concepts of the construction process model with identified participants can be used as the guidelines for starting new building projects.

The third advance produced by this research is the integration of the construction process model and the artificial intelligence environment. The advantage of such integration will be especially important for educating and training inexperienced construction participants.

The fourth advance of this study is the attachment of 'knowledge management' to construction process model. Knowledge management is a newly raised topic in recent years. The aim of knowledge management is to learn from the previous experience of the product development process in order to improve the quality and the production process of product. The success factors for construction process have been generally based on literature review and these factors have been 'linked' to the relevant activities. Therefore, it has set up the 'warning' system for the user to alert what success factors they have ignored or if they did not finish a certain activity. The use of this tactic reminds the user what factors have been ignored if they did not do certain activities.

Finally, the fifth advance exemplified by this study is of an application nature. The prototype system developed in a PC computer using the 'XpertRule' shell endorses the proposition that artificial intelligence technology offers techniques, which facilitate the representation and manipulation of the construction process model. The concept of knowledge representation and elicitation methods provided by this prototype system will be of value during the future development of a commercially viable knowledge based system in construction process modelling

11.4 Limitations of CONBPS

A self-assessment of this research illustrates some weaknesses. They are presented here in the hope that prospective researchers wishing to build on this work may address them in future development.

CONBPS can be applied to 'new building' construction projects which use the traditional procurement strategy only. While the aim is to make the system more 'focused', this also limits its general applicability. Besides, the development of CONBPS into an expert system has finished at the 'concept design stage', therefore only the first four construction stages within the RIBA Plan of Work are considered, this is the second limitation.

Because of the financial limitation, CONBPS cannot be put in web so as to be more convenient to the users who access it. Also due to limitation of time and resources, CONBPS is solely produced as a 'prototype'. The development of this system is aimed at justifying the usefulness of the idea rather than producing a completed system. Therefore, the completed system has only focused on the 'inception' stage with the consideration of several success factors only.

The final limitation of this project is that of the 'defined' participants and activities. This system has identified all commonly involved participants as well as their responded activity in a traditional procurement strategy. It can be widely used for common or standard new building projects. However, it cannot be applied to complex projects, as these may need the involvement of some specialist consultants. On the other hand, some simple projects may not employ all the consultants who are identified in this system, for example, the architect may act as project manager and planning supervisor. The limitation of this system is not able to 'add' or 'delete' the parties and activities freely.

11.5 Suggested directions for future research

The development of a knowledge-based system is an exploratory and evolutionary process. It is obvious that the quality and the completeness of a knowledge base will determine the validity and accuracy of a viable operational knowledge based system. With this in mind, the outcome of this research can only provide a starting point for future system development. The following are proposed as possible areas for further research.

The development of CONBPS focuses on the conceptual design stage at the preliminary version and completed CONBPS focuses on inception stage only. This research can be extended to the tender and construction stages. Moreover, it focuses on new building projects which use the traditional procurement strategy. This research idea can be expanded to other procurement strategies and other types of construction works.

The second aspect is to put CONBPS into an 'accessible' location for the users, for example, on the web. It can facilitate the users to access the system at the same time. Also, it is more convenient for them to access the most updated information.

The third aspect that should be considered in the future research is to incorporate the comprehensive list of success factors in the construction process model. The list of the success factors for the construction process has been developed in section 2.4. The suggested way for linking all the factors to the construction activities is to do a comprehensive questionnaire survey. The list of the success factors and the list of activities are sent out to all the identified participants with a request to match the factors and the activities. Afterwards, some analysis is needed in order to identify the pattern of matching between the factors and activities.

The fourth aspect of future research is to improve the system so to be able to let it add the parties and activities. In order to achieve this purpose, it is necessary to partially re-write the current system in traditional programming language, like Visual Basic. This is because there is an established linkage between XpertRule and Visual Basic, therefore, it is easier to establish the connection between these two programming languages. As discussed in section 11.2, the advantage of using XpertRule is the ease of incorporating practitioners' opinions. After receiving these opinions, it is worthwhile to partially rewrite the system in order to enhance its flexibility.

The final aspect of future research is to provide the related recommendation to the invalid answer at the interim report. For example, if the user provided an invalid answer for activity one, it should provide the recommendation for activity one only instead of providing recommendation for all activities in section one. As with the fourth area of future research, this function can be easily added to a traditional programming language. The advised method for achieving this purpose is to rewrite the interim report section by another programming language. Again, the advised programming language is 'Visual Basic'.

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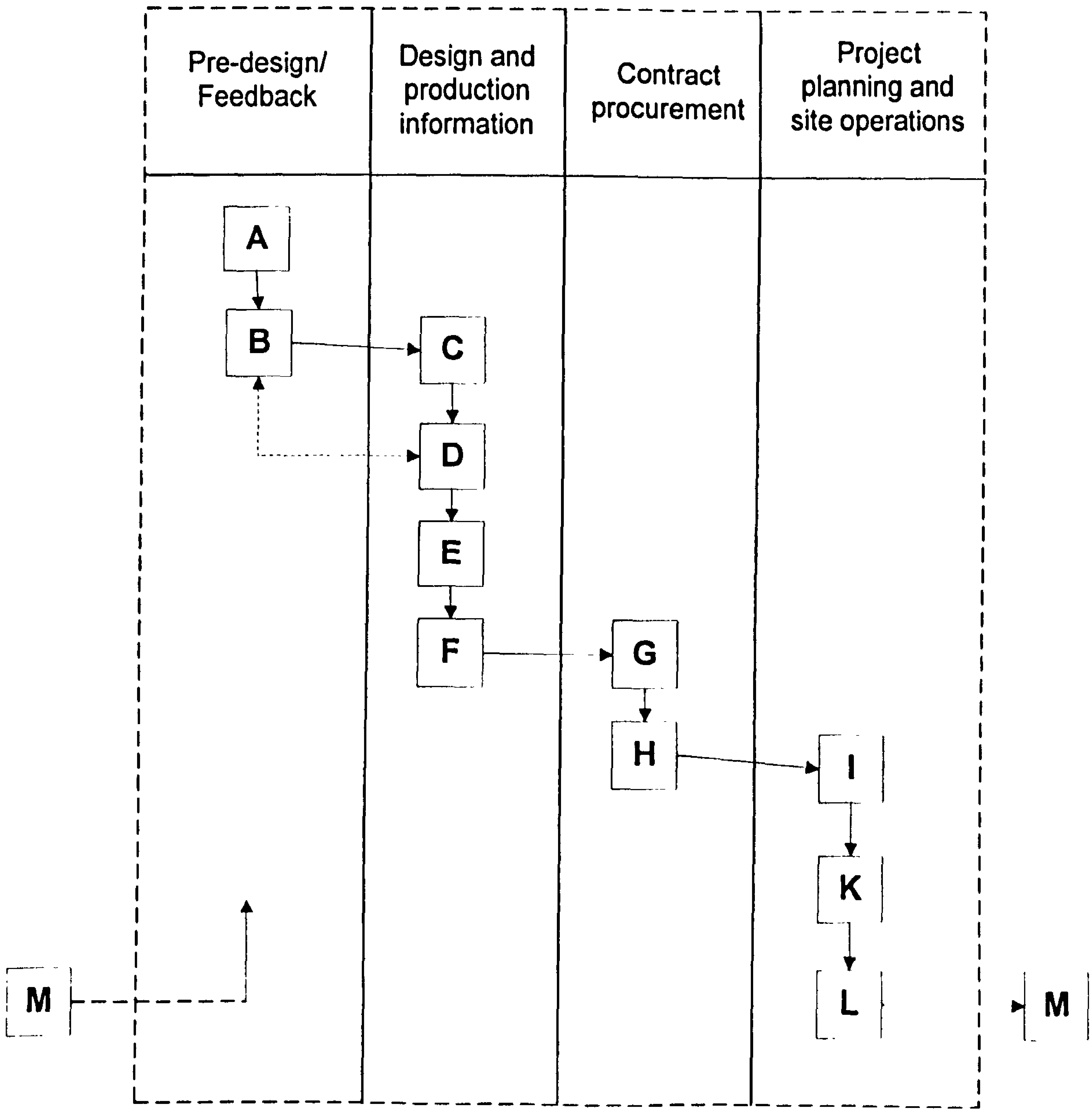
Appendix 1

RIBA Plan of Work

Traditional Plan of Work sequence



A – Inception
B – Feasibility
C – Outline Proposals
D - Scheme Design
E – Detailed Design
F – Production Information
G – Bill of Quantities
H – Production Information
J – Project Planning
L – Completion
M – Feedback

Appendix 2

Theoretical framework for prototype CONBPS

Stage A : Inception (1)

Criteria	Participants	No.	Participants
H	CL	1	Prepare statement of need and stated when should the project finish
Q	CL	2	Negotiate with the competent architect about their appointment
T C Q	A	2a	Meet client to discuss about his requirement, budget, project timetable and obtain necessary information
S	CL – No → Ignore activity 10, 10a, 10b	2b	Determine whether the project falls within scope of CDM Regulations
Q	A	3	Start Environmental Impact Assessment (EIA) & produce Environment Statement (ES)
Q	CL	3a	Identify clearly the environmental orientation of the project in relation to the aim, objects, resources and management
H	A – No → Go back to activity 2	4	Accept appointment from the client
H	CL – No → Discuss with client	5	Provide a precise and concise brief to the appointed architect
Q	CL	5a	Emphasise the environmental orientation established during EIA in the outline brief
Q	A	6	Inform client about their job responsibilities
Q	A	6a	Advise client about the necessity of appointment of other consultants
S	A	6b	Must take reasonable steps to ensure that the client aware of his duties under the CDM Regulations before starting design work on the project
H	A	7	Set the defined and quantified objective for each stage
H	CL – No → Go back to activity 2	7a	Discuss with architect about feasibility of achieving their objective
H	A	7a	Discuss with the client about feasibility of project
H	A	8	Arrange for and assist in the selection of other consultants
H	CL	8	Arrange for and assist in the selection of consultant
C	CL	8a	Select the appropriate principal consultants
C	Q	8a	Discuss terms of appointment of service to be provided and fees required
H	Q – No → Go back to activity 8	8b	Discuss with the consultants about their terms of appointment
Q	CL	9	Discuss with architect about their commitment to constructability
S	CL	10	Appoint an agent for CDM Regulations
S	CL	10a	Appoint a representative to act in specified matters about CDM Reg.

Stage A : Inception (2)

Criteria	Participants	Participants	
S	CL	10b	Appoint Planning Supervisor
C T	P	10c	Obtain the client's requirements, budget and project timetable
S	P	10d	Inform the client that their duties under the CDM Regulations
S	P	10e	Establish a record of the principles and decisions relating to health and safety identified in feasibility study
S	P	10f	Check with the lead designer about the information concerning health & safety
S	P	10g	Ensure that all designers co-operate in respect of CDM Regulations matters, discuss with the lead designer how he proposes to manage design, and what should be contained in the project quality plan
C	A	11	Advise client on selection and suitability of the site
C	A	11a	Obtain information from the selected site
Q	CL	12	Develop a training plan for different level project team member
Q	A	13	Ensure the adequate level of project team commitment

Stage B : Feasibility (1)

Criteria	Participants		Participants
H	A Q CL P	1	Participate and contribute to project meeting
H	A	2	Advise the client on methods of procuring construction
Q	CL	3	Consider environmental orientation when choosing the procurement method
H	A	4	Assist the client in preparation of the client's requirement
Q	A	4a	Assist client in establishing obj. and measures for constructability
H	A — No → Discuss with client	5	Carry out studies to determine the feasibility of client requirements
T	CL	6	Provide adequate information assistance and resources to architect
S	A	6a	Ensure pass all relevant informtion to PS
Q	A	6b	Recognize the inherent complexity and technology of design
C	A	7	Carry out site study
C	Q	7	Carry out construction cost study
Q	CL	7a	Consolidate the findings & suggestions of EIA during site investigation
S	P	8	Notified the project to HSE
S	P	8a	Identify any client's agent and check declaration to HSE
S	A	9	Allocated adequate resources to project in respect of req. of CDM Reg.
S	A	9a	Make improvement on health and safety issues
S	A	9b	Prepare to include the information on site feature into the H&S Plan
S	P	10	Advise the client about designer's competency on managing H&S Plan
H	P — No → Discuss with client	10a	Alert client about their duties on H&S
H	P — No → Discuss with architect	10b	Ensure designers comply their duties under the CDM Regulations
S	P	10c	Identify investigations or surveys required in connections with the CDM Regulation and report to Client
S	A	10d	Agree the nature and format of the pre-tender H&s Plan with PS
S	P	10e	Ensure be informed that the relevant health and safety are included in the feasibility studies work

Stage B : Feasibility (2)

Criteria	Participants	No.	Participants
C	Q	11	Provide cost advice on preparing proposals
C	CL	11a	Prepare budget for environmental management in cost assessment
C	Q	11b	Prepare initial budget estimate to test feasibility of the proposal
C	CL	12	Quantify and make financial provision for any risk in project
C	A	12a	Managing project risk through reduction, avoidance or transfer
T C	A	13	Set up procedures to minimise and avoid dangers in site environment
C Q	A	14	Apply value mgmt. to identify and evaluate the feasibility options
T C Q	A	15	Collaborate with consultants to carry out feasibility design work
H	CL	15a	Receive feasibility report and discuss the report with project team
H	CL (If modify, go back to appropriate activity)	15b	Decide to abandon or continue, instruct architect accordingly
T C Q	A	16	Prepare final report to client on feasibility of project
H	A	16a	Draw together the environmental inf. & balances with other project criteria
C Q	A	17	Recommend client to appoint further consultants
C Q	CL	18	Appoint further consultants
H	A	19	Review alternative design, construction approaches and cost implications with the client
T	A	20	Advise the client on the necessity to obtain planning permission, approvals under building acts and/ or regulations and other statutory requirements

Stage C : Outline Proposal (1)

Criteria	Participants		Participants
H	CL	1	Ensure that financial and other resources for projects are available
Q	CL	2	Develop constructability team
C	CL	3	Provide all information required by the project team
C	Q	3	Obtain all client's requirement on cost and contract
Q	A	3a	Produce diagrammatic analyses of client requirements
C	Q	3b	Prepare an approximation of construction cost
C Q	A	4	Study and analyse similar project and visit them
C Q	A	5	Consider any hazards and risks during the design process
C Q	A	5a	Give adequate regard to the hierarchy of risk control
H	A	5b	Prepare significant risk management scheme
S	CL	6	Provide health and safety information to Planning Supervisor
S	A	6a	Find ways to control the significant health and safety risk
S	P	6b	Identify responsibilities of designer for elements relating to health & safety
S	A	6c	Remind other consultants about their responsibilities for H&S
S	P (No → Remind designer)	6d	Ensure designers take proper account of H&S in their design
H	A	7	Incorporate TQM concept in the outline proposal
Q	A	7a	Establish policy to steer, manage and support TQM activities
H	A	8	Consider value management in the outline proposal
H	A	9	Set up system to ensure client satisfied at each stage
S	P	10	Establish procedures for collating and storing health and safety information
S	P	10a	Establish a programme and procedure for reporting, management for reporting and changes and design co-ordination of health & safety matters
S	P	10b	Establish format of information for pre-tender Health and Safety Plan
S	P	10c	Advise Client on a maximum of six prospective designers in relation to the CDM Reg. and their health and safety policies and procedures

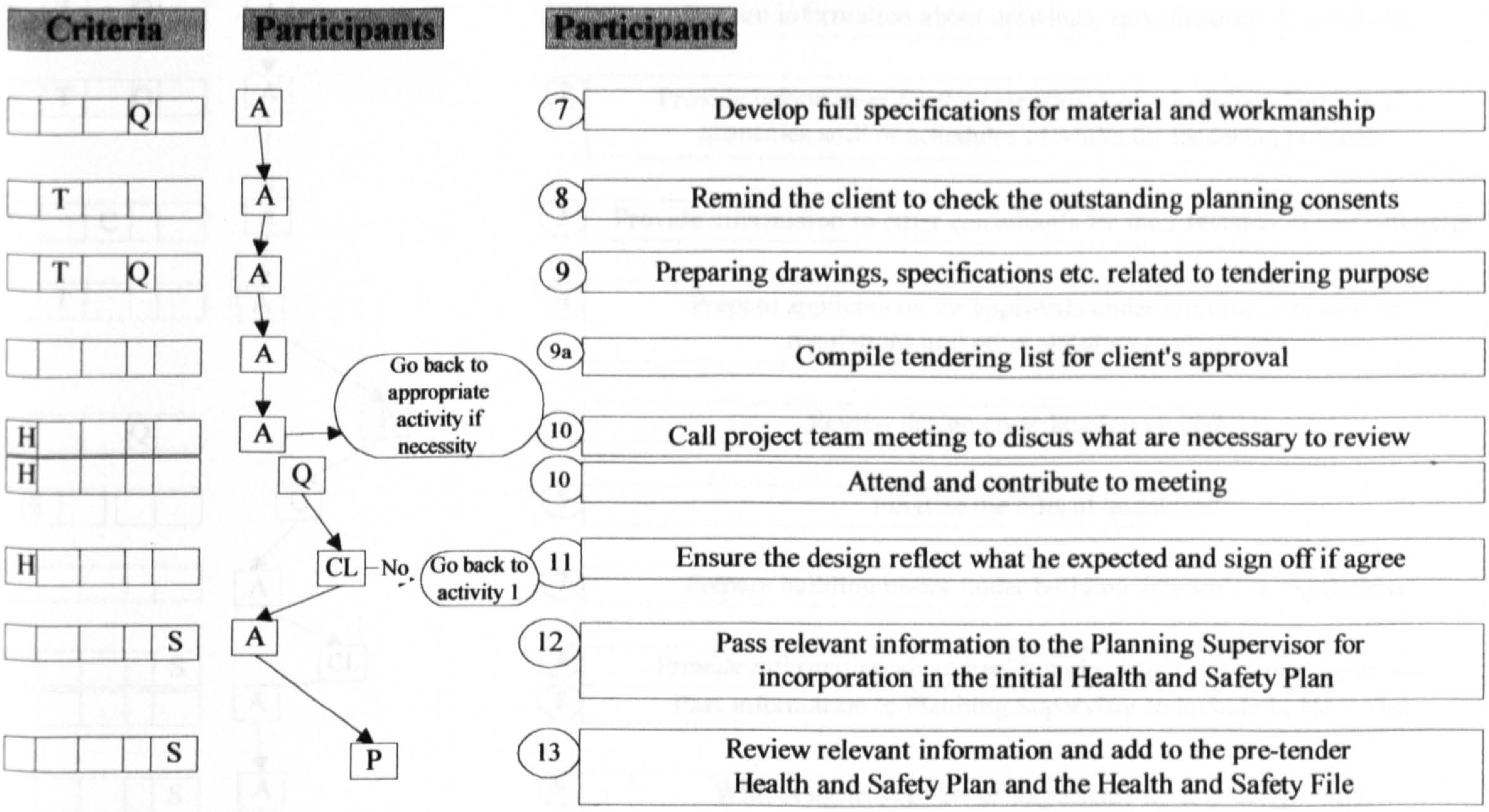
Stage C : Outline Proposal (2)

Criteria	Participants		Participants
T C Q	A	11	Start to prepare outline scheme
T C Q	Q	11	Collaborate in preparation of outline scheme
T C Q	CL	11	Participate to prepare outline scheme
C	Q	12	Confirm approximate cost estimate of project
Q	A	13	Assemble all sketches and contribute to design dossiers
Q	Q	13	Contribute to design dossiers
C	A	14	Assist QS in preparing outline cost plan and discuss cost range
C	Q	14	Prepare outline cost plan
C	Q	14a	Prepare cash flows for use with overall project cost calculation
H	Q	14b	Develop a proper cost control system
S	P	15	Start to prepare pre-tender Health and Safety Plan
S	P	15a	Monitor health and safety implications of any proposed changes to production information and update pre-tender H&S Plan
S	P	15b	Start to prepare Health and Safety File for the Project
Q	A	16	Prepare special drawings, models or technical information for client
T	A	17	Prepare proposals and make application for outline planning permission
H	CL (If not satisfy, discuss with architect)	17a	Receive outline proposal, consider outstanding issues & give instruction to architect
H	A	17b	Finish outline proposal
Q	A	18	Advise client on the issues about developing strategic brief
Q	CL	18	Develop strategic brief
Q	A	18a	Ensure all environmental information is clear and available to the scheme design consideration in reviewing the brief
T C Q	A	19	Advise client on the issues about developing Project Execution Plan
T C Q	CL	19	Develop Project Execution Plan
T	A	20	Prepare Services Timetable for the completion of the Services

Stage E : Detail Design (1)

Criteria	Participants	No.	Participants	Note
Q	A	1	Start to prepare detail design	
Q	A	1a	Translate the scheme design specifications into detailed and workable design concepts including any environmental aspects that have been identified	
Q	A	1b	Buy the specialist design if necessary	
S	A	1c	Seek advice from principal supervisor during design process	
H	CL	1d	Apply constructability concepts and procedures	
H	A	1e	Do not modify the basic design after sign-off packaged information	If not satisfy, go back to activity 1
C	A	2	Receive all drawings from consultants and sent to QS for cost check	
C	A	2a	Carry out cost studies and cost checks	
C	Q	3	Prepare cost plan and cost check regularly	
C	A	3	Receive cost plan and cost check from QS	
T C Q	A	3a	Update drawings and detail design and inform QS of any changes	
H C	Q	3b	Start to prepare bills of quantities	Ensure it is the appropriate time
Q	A	4	In considering design alternatives: determine environmental options and balance equally with other project requirements	
	A	4a	Specifications and contract documentation: clearly interpret and present environmental needs in detailing drawings	
	A	5	Consult with building control authorities on developed design proposals	
	A	5a	Consult with fire authorities on developed design proposals	
	A	6	Advise on and recommend form of building contract and explain the client's obligations thereunder	
	A	6a	Obtain the client's approval of the type of construction, quality of materials and standard of workmanship	
	A	6b	Ensure that client and user environment requirements are met during detailed design study	
H	A	6c	Ensure that design meets all environmental needs before committing to construction stage in finalising detailed design	

Stage E : Detail Design (2)



Stage F : Production Information (1)

Criteria	Participants	No.	Participants
T Q	A	1	Prepare information about drawings, specifications & schedules
T Q	A	2	Provide information for the preparation of schedules of rates and/or quantities and/ or schedules of works for tendering purposes
C	A	3	Provide information to other consultants for their revision of cost estimates
T	A	4	Prepare applications for approvals under building acts and/ or regulations and other statutory requirements
Q	P	5	Review design co-ordination procedures
H	Q	6	Finalize the bills of quantities
	A	7	Prepare building notice under building acts and/ or regulations
S	CL	8	Provide information about health and safety to Planning Supervisor
	A	8	Pass information to Planning Supervisor to include in H&S Plan
S	A	9	With designers review arrangements for any design input required from contractors and specialist post-tender
T C	A	10	Prepare contract particulars, documents and drawings for tendering
T C	Q	10	Participate in preparing tender documents and contract particulars
T	A	10a	Distribute preliminary inquiry to identified contractor at least 4-6 weeks before dispatch of tender document. Distribute preliminary inquiry to identified contractor at least 4-6 weeks before dispatch of tender document
T S	P	11	Ensure to receive all relevant information
S	P	11a	Preparef a pre-tender stage Health and Safety Plan
C	P	11b	Discuss with the quantity surveyor how he intends the health and safety items to be priced
	P	11c	Report to client on health and safety principles
	A	12	Submit plans for proposed building works for approval of landlords, founders, freeholders, tenants or other as request by the client

Stage F : Production Information (2)

Criteria	Participants		Participants
T	A	13	Prepare main contract tenderers list; recommend shortlist main contract tenderers for client's approval at least two months before inviting tender
H	CL	14	Make decisions on the issues about tendering
S	P	15	Review further relevant information from designers and add to pre-tender Health and Safety Plan under the Health and Safety File
T	A	16	Consolidate all information at this stage and prepare report

Stage G : Bills of Quantities

Criteria	Participants	No		Participants
C	Q		1	Give client advice on tendering and contractual arrangements
H	A		2	Agree or confirm tendering agreements and techniques
T	A		3	Start to finalise all information for contractor to prepare tender document
S	A		4	Consolidate the necessary health and safety issues at tender process; give enough time for principal contractor to prepare their tender document
C	Q	Go back to activity 1	5	Provide up-dated cost estimate to client after tendering document completed
C Q	A		6	Set contractor selection criteria
C Q	A		6a	Issue invitation of tender to the selected contractor
H	A	Ask relevant contractor	6b	Invite selected contractors to confirm their interest on tender
T	A		6c	Advise the client about issues of inviting tender
T	A		6d	Notify tendered if there is any change of information about project
H S	A	Discuss with Planning Supervisor	7	Ensure the H&S Plan has been finished before appointing contractor
S	P		7a	Issue pre-tender Health and Safety Plan for inclusion with tender documents
S	P		8	Certify to Client readiness to proceed to tender in respect of the CDM Reg.
C Q	Q		9	Advise on contractual insurance responsibilities
C Q	CL		9a	Arrange the issues about insurance
C Q	CL		9b	Prepare building contract and insurance of project

Stage H : Tender Action (1)

Criteria	Participants		Participants
T	Co	1	If contractor intend to withdraw their willingness to tender, they should notice their intention before submission of tender documents
	A	2	Select the shortlist tenderers and inform the declined tenderers
H	A	2a	Advise the client's approval of list of tenderer, maximum is six
S	P	2b	Advise Client on a maximum of six prospective tenderers in relation to the CDM Regulations, and attend interviews as necessary
H	A	3	Evaluate bids on basis of price, quality and while life costs
H	CL	3a	When select contractors, should consider contractors' safety record, competency & reputation of work quality other than bids
Q	CL	3b	Consider constructability as part of contractor pre-qualification
Q	A	4	Arrange tenderers to inspect drawings and other documents
T	A	5	On the day stated in the preliminary invitation, all tender document should be available for collection or dispatch them by first class post
	Co	5a	Undertake an environmental risk assessment as part of the tendering process
	Co	5b	Identifying key environmental effects that will need to be managed on site
	Co	5c	Developing an environment management plan (EMP)
	Co	6	Distribution of good practice guidelines to project staff relevant to the key issues identified
	Co	6a	Determination of audit procedures between the corporate organisation and the project site
	Co	6b	Check whether tender document are deficient or contain unacceptable alterations. If so, inform the issuing authority or the architect a.s.a.p.and preferable of not less than 10 days before the tenders are due
	A	6c	Allow adequate time for the Planning Supervisor to check the preferred tender's health and safety and for the tenderer to develop a construction phase Health and Safety Plan sufficiently to comply with the CDM Regulations.
	A	6d	Should allow at at least four weeks to tenderer to prepare their tender
S	Co	6e	Provide copies of their safety policy statement with tender document
	CL	7	Arrange pre-tender meetings with contractors

Stage H : Tender Action (2)

Criteria	Participants	No.	Participants
T	A	8	Do not accept late tenders
H	CL (No → Remain relevant contractor)	9	Ensure to receive all tender document from tenderers
T	A	9a	Open tender as soon as possible after receiving
T C	A	10	Appraise the received tenders
S	P	10a	Appraise response to pre-tender H&S Plan, including any method statements, program and other relevant documents submitted by preferred tenderer
	P	10b	Review Principal Contractor's development of the H&S Plan
S	P	10c	Advise Client with regard to the appointment of preferred tenderer as Principal Contractor
C	A	10d	Ask every tenderers to supply a list of tender price
C	A	10e	Ask the lowest tenderer to submit his priced BQ a.s.a.p.
S	P	10f	Notify the Client when the Health and Safety Plan has been developed sufficiently by the contractor
C	Q	11	Examine BQ carefully and detect any errors in computations
C	Q	11a	Take appropriate action if any error in tender document was detected
C	A	12	If the successful tenderer's price exceed client's budget, recommend a price for negotiation with this successful tender
C	Co	12	Negotiated with architect about the price for tender
T	A	12a	Proceed to next lowest tender if negotiation fail. Repeat if necessary
H	A	12b	If all negotiation fail, call for new tender
	A	13	Providing practice notes to site staff on environmental management procedures to be adopted
	A	14	Report to client about the result of tender
	CL	15	Prepare the building contract and arrange for it to be signed
S	A	16	Ensure CDM provisions are properly incorporated in the contract
	A	17	Prepare the building contract and arrange for it to be signed
	CL	18	Appoint principal contractor
H T	A (No → Take appropriate action)	19	Check with client that nothing prevent contractor to start to work

Stage J : Project Planning (1)

Criteria	Participants	Participants	
H	A	1	Prepare contract documents, send it to contractor and client for signature
	Q	1	Checking the contract document
	CL	1	Check contract document. Sign it if no problem
	Co	1	Check contract document. Sign it if no problem
C Q	A	2	Ensure all legal, financial insurance arrangements are place
	Co	3	Start to co-ordinate with sub-contractors
	A	4	Hold 1st project meeting
	Q	4	Contribute to 1st project meeting
	CL	4	Contribute to 1st project meeting
	Co	4	Contribute to 1st project meeting
Q	Co	5	Briefing all staff on the environment impact issues identified in project environmental planning
Q	Co	5a	Conducting a site tour to familiarize the project team with the site and its relationship to the areas of environmental risk
S	P	6	Ensure designer and contractor take proper account on health and safety
S	P	6a	Agree with client and contract administrator/ employer's agent procedures for health and safety matters during the construction phase
S	P	6b	Notify further project particulars to HSE
H	A	6c	Establish reasonable procedure to reduce health and safety problem on site
	A	7	Write to Clerk of Work to confirm their appointment and duties
C	A	8	Identify construction risks in qualitative and qualitative terms
C	Q	9	Prepare the pre-construction cost report
T	CL	10	Co-operate with sub-contractor to prepare pre-contract planning
T	Sc	10	Contribute to pre-contract planning as required
Q	A	11	Ensure to give adequate training to on-site workers
Q	A	12	Providing training in the use of the procedures that will be used to plan, monitor and control environmental effects
Q	A	12a	Using an item checklist for environmental risk assessment and risk monitoring

Stage J : Project Planning (2)

Criteria	Participants	Participants	
Q	A	12b	Developing self-audit/ review sheets for use by environmental management managers
Q	A	12c	Providing guidance notes on potential actions that are arised by environmental problem arise
Q	A	12d	Specifying designated senior (corporate) level managers who can be consulted easily and quickly should problematic environmental matters arise that cannot be resolved on project site level
S	Cl	13	Ensure all contractors aware the requirements of CDM Reg.
S	Cl	13a	Ensure all sub-contractors complies their health and safety duties
C Q	A	14	Receive contractor's insurance policy for checking
S	P	15	Ensure a Health and Safety Plan is prepared before arrangements are made for the appointment of a contractor
	A	16	Hold 2st project meeting
	Q	16	Contribute to 2st project meeting
	Cl	16	Contribute to 2st project meeting
	Co	16	Contribute to 2st project meeting

Stage K : Operation on Site (1)

Criteria	Participants		Participants
	A	1	Hold regular site meeting
	Q	1	Contribute to regular site meeting
	CL	1	Contribute to regular site meeting
	P	1	Contribute to regular site meeting
	Co	1	Contribute to regular site meeting
	Sc	1	Contribute to regular site meeting
	Co	2	Hold regular production meeting
	A	2	Contribute to regular production meeting
	Q	2	Contribute to regular production meeting
	Sc	2	Contribute to regular production meeting
S	Co	2a	Should discuss health and safety issue at each site meeting
	A	3	Administrate the terms of the building contract
S	CL	4	Ensure that construction work does not start before a H&SPlan has been prepared for the construction phase
S	Co	5	Ensure co-operation between all contractors working with any rules on the site with regard to the CDM Regulations
Q	A	6	Continue general supervision of the project
C	Q	6	Advise architect on financial implication of administration of contract
T C	Co	6	Notify architect any claim for extension of time and cost
C	A	7	Maintain running financial statement to facilitate cost control
C	Q	7	Inform client about running cost and get approval for overrun
C	CL	7	Be notified financial statements, approve justified increased cost
C	Co	7a	Provide QS all necessarily information promptly and constantly
C	Sc	7a	Provide QS all necessarily information promptly and constantly
S	Co	8	Provide appropriate communication about health and safety issues
S	P	8	Monitor health and safety performance
S	A	8a	Make contribution to health and safety of site through design & planning
S	P	8a	Ensure all risks to health and safety has been assessed
S	P	8b	Ensure adequate health and safety arrangement
S	A	8c	Warn the contractor about the CDM Regulation issues
S	P	8d	Identify hazards of construction site and ask contractor to control

Stage K : Operation on Site (2)

Criteria	Participants		Participants
S	P	8e	Ensure construction work compile under H&S plan
S	Co	8e	Implement Health and Safety Plan and keep it up-dated
S	A	8f	Provide information for health and safety file
S	Co	8f	Provide information for health and safety file
S	Sc	8f	Provide information for health and safety file
S	P	8g	Review design input from contractors and specialists. Ensure that health and safety implications are considered and relevant information provided to the Principal Contractor
S	A	9	Using appropriately qualified personnel, carry out audits of health and safety audits at regular intervals during the construction phase and report to client
S	A	9a	Using appropriately qualified personnel, advice Client on the health and safety implications of any temporary works
	P	10	Review design co-ordination procedures in respect of design variations or design input by contractors
S	Co	11	Arrange First Aid facilities and warning signals
	Co	11a	Institute procedures for regular inspection and spot checks
S	Co	11b	Make sure only authorized people allowed in the site
S	Co	11c	Ensure that all operative on site, including self-employed, are able to discuss health and safety matters, and he must take account of views expressed
S	Co	11d	Give reasonable directions as necessary to any contractor concerning compliance with duties under the CDM Regulations
C	Q	12	Update project accounting constantly
C	Q	12a	Secure proof of previously authorized payment to sub-co or suppliers
C	Q	12b	Ascertain the final amount of fee
Q	A	13	Monitor contractor's work regularly
S	A	13a	Consider measures which will help workers to reduce accidents
Q	Q	13b	Execute constructability procedure

Stage K : Operation on Site (3)

Criteria	Participants		Participants
T	A	13c	Report to client regularly about progress of work
H	A	13d	Advise client to terminate contractor if they have serious default
C Q	Cl	14	Maintain project diary & take photos of any significant development
Q	A	15	Initiate action for commissioning and testing at appropriate time
Q	A	15a	Remind client of to attend commissioning and testing
T	A	16	Inform consultants and contractors project is near completion
S	P	17	Ensure H&S file finished and pass to client after project completed
Q	A	18	Start to prepare of Building Owner's Manual and record drawings
Q	Q	18	Prepare materials for Building Owner's Manual and record drawings
Q	P	18	Prepare materials for Building Owner's Manual and record drawings
Q	Co	18	Prepare materials for Building Owner's Manual and record drawings
Q	Sc	18	Prepare materials for Building Owner's Manual and record drawings

Stage L : Completion (1)

Criteria	Participants		Participants
T	A	1	Two weeks before date of practical completion, instruct contractor to make sure site ready for preliminary inspection
Q	Co	1	Make arrangement for and collaborate with architect's inspection
	A	1a	Remind the client to insure the building before occupation
Q	A	1b	Join with client to inspect building
Q	CL	1b	Inspect building, list outstanding work and develop execution program for these work
	A	1c	Provide drawings showing the building and the main lines of drainage
	A	1d	Arrange for drawings of building services installation to be provided
T	A	2	Obtain contractor's forecast date of practical completion
T	A	2a	Inform the client of proposed handover date and procedures
	A	2b	Keep a close watch on arrangements for commissioning and testing of plant & installations
	A	3	Hold handover meeting
	Q	3	Attend handover meeting
	CL	3	Attend handover meeting
	Co	3	Attend handover meeting
	Sc	3	Attend handover meeting
	A	4	Determine necessary action & instruct contractor to do accordingly
H	A	4a	Generally inspect materials delivered to the Site
H	A	4b	As appropriate instruct sample taking and carrying out tested materials, components, techniques and workmanship and examine the conduct and results of such tests whether on or off-site
	A	4c	Provide specially prepared drawings of a building as built
H	A	5	Inspect buildings before the end of defect-liability period; check to ensure incomplete work has been completed; prepare schedule of defects and define contractor's responsibility. Prepare separate schedules of client modifications
H	A (If not satisfied, discuss with contractor)	5a	Final inspection of building
C	Co	6	Submit final accounts to contractor
C	Sc	6	Obtain outstanding final accounts from sub-contractors

Stage L : Completion (2)

Criteria	Participants		Participants
C	Q	6a	Obtain remaining invoice & accounts; notify any outstanding claims
C	Q	6b	Prepare the final project account
C	Q	6c	Send final account to architect and contractor
H	A	6d	Read final account, discuss with QS if necessary
Q	A	7	Ensure that contractors arrange all issue for maintenance
Q	A	7a	Remind contractor to check M&E and other operating manuals
Q	A	7b	Prepare maintenance program and arrange maintenance contracts
Q	A	7c	Compile maintenance and operational manuals
S	P	8	Receive, review & collate information from Designers, Principal Contractors, contractor and specialists and add them to the Health and Safety File
H	P	8a	Deliver H&S File to the client, preferably in person, to explain its importance and the need for its safe custody. Record this action in writing
H	CL	8b	Take reasonable steps to keep the Health and Safety File secure, to make it available to those who might need it for future maintenance or alternations and to pass it on to whoever acquires an interest in the property
S	P	9	Advise Client on health and safety aspects in the event that correction of defect or post completion alteration is noticeable as a separate project under the CDM Regulations
Q	A	9a	Give general advice on maintenance
	A	9b	Prepare valuations of work carried out an completed
Q	CL	9c	Ensure the environmental assessment aspect of the project is satisfactory

Stage M : Feedback

Criteria	Participants		Participants
Q	A	1	Continuing response for the issue during the defect liability period
Q	A	2	Assess suitability of project in satisfying user needs and whole life design. Provide feedback for future improvements
T C Q	A	3	Check that whether the result of the project meets the requirements of the design professional, defined scope of work and budget
T C Q	A	4	Check that whether the result of the project meets the requirements of the contract performance of work, on a reasonable schedule and permits a reasonable profit
S	A	5	Check that whether the result of the project meets the requirements of regulatory agencies (the public) as to public safety and health; environmental considerations
	A	6	Check that whether the result of the project meets the requirements of protection of public property including utilities and conformance with applicable laws, regulations, code and policies
T C	Q	7	Check that whether the result of the project meet budget to obtain adequate field information prior to design; provisions for timely decision by owner and design professional; and contract to perform necessary work at a fair fee with adequate time allowance
T C	Cl	8	Check that whether the project meet the requirements of the owner as to functional adequacy, completion on time and within budget; life-cycle costs and operation and maintenance
H	CL	9	Examine the building again when approaching the end of defect liability period
S	A	10	Before issuing a schedule of defects at the end of the defect liability period, discuss any likely CDM Regulation implications with the Planning Supervisor
Q	A	11	Issue Final Certificate after the end of defect liability period

Ensure no problem, otherwise, discuss with architect

Appendix 3

Decision trees of prototype CONBPS

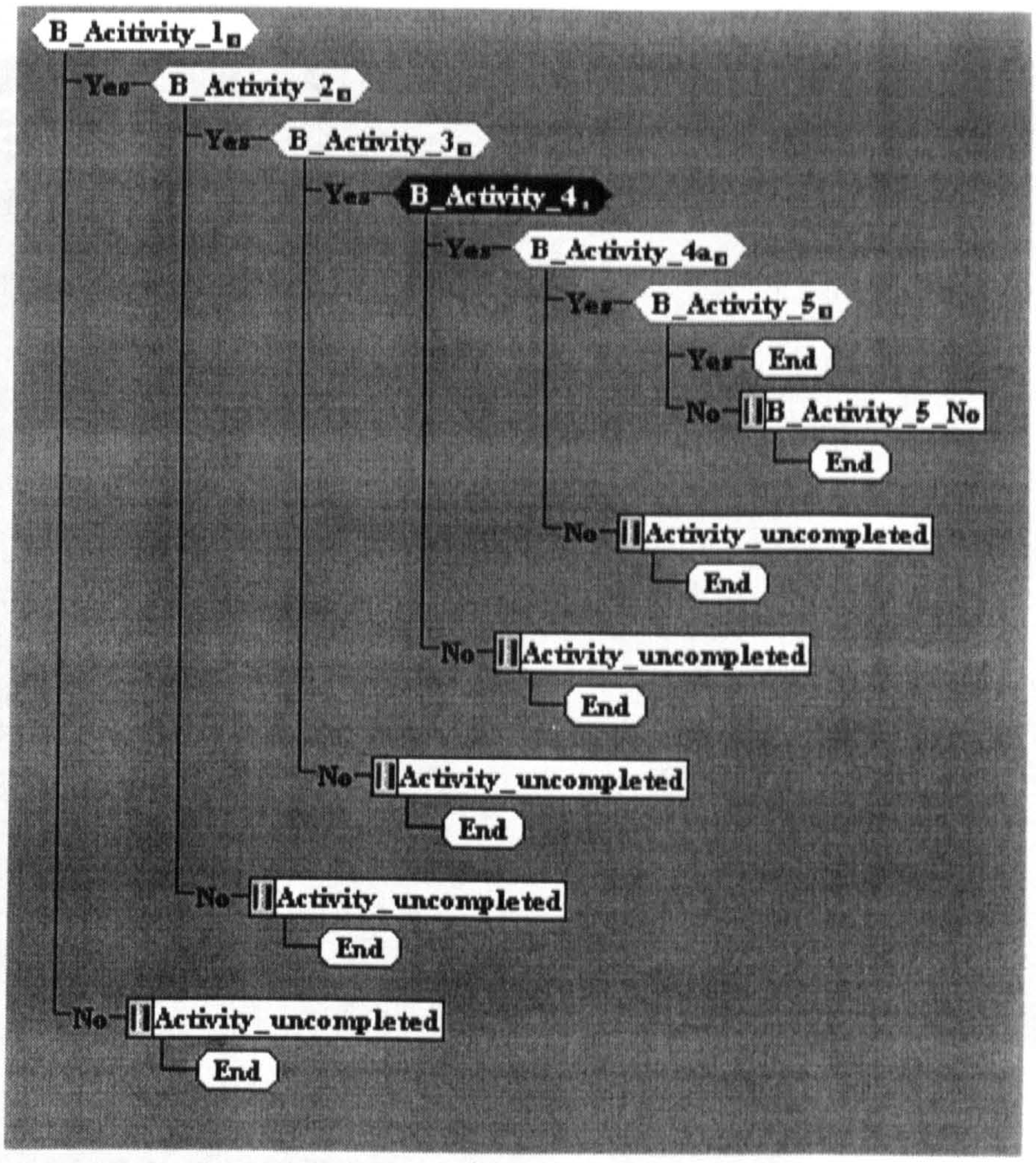


Figure 3.1 Decision tree of Stage B – Preliminary section

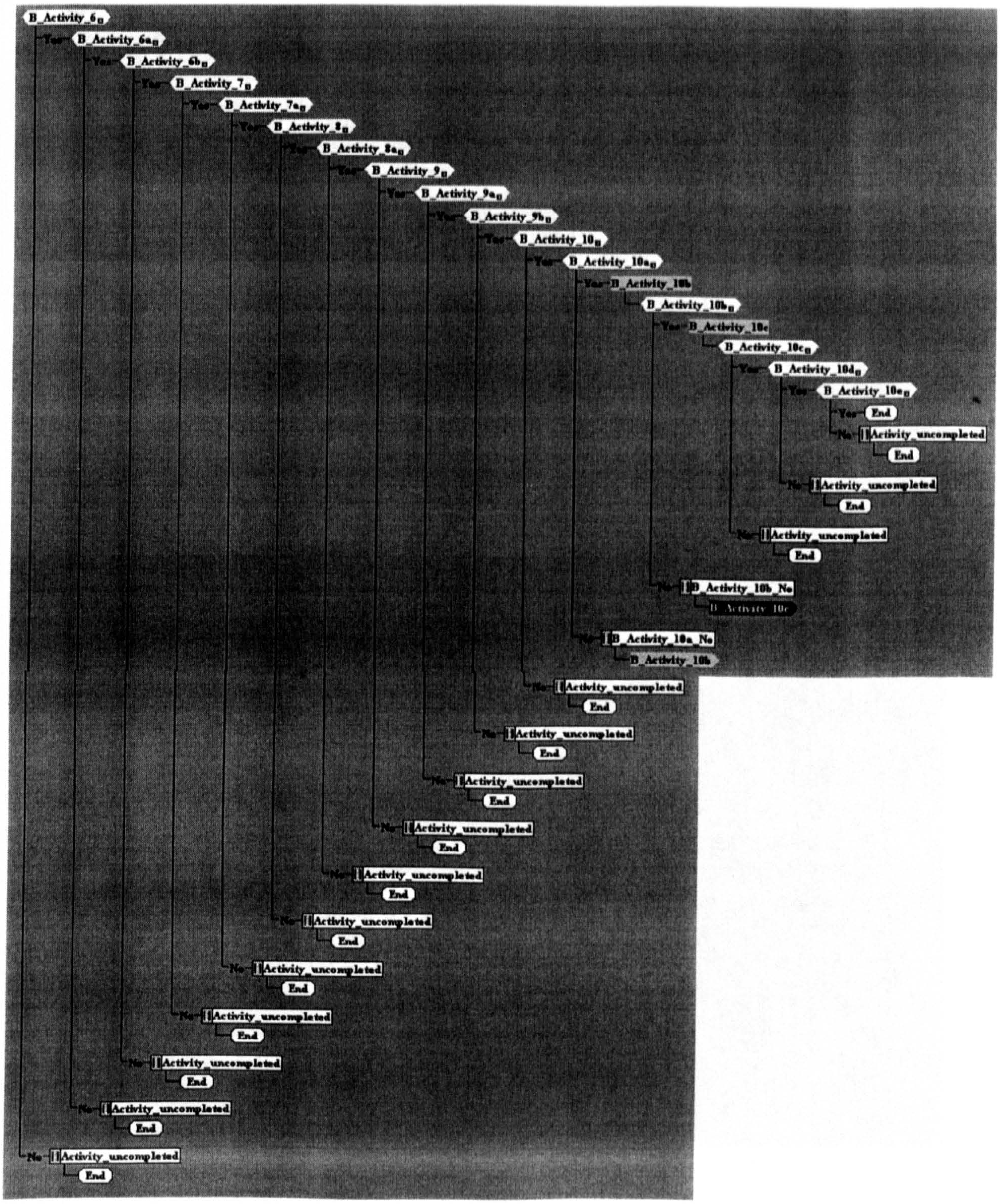


Figure 3.2 Decision tree of Stage B – Middle section (1)

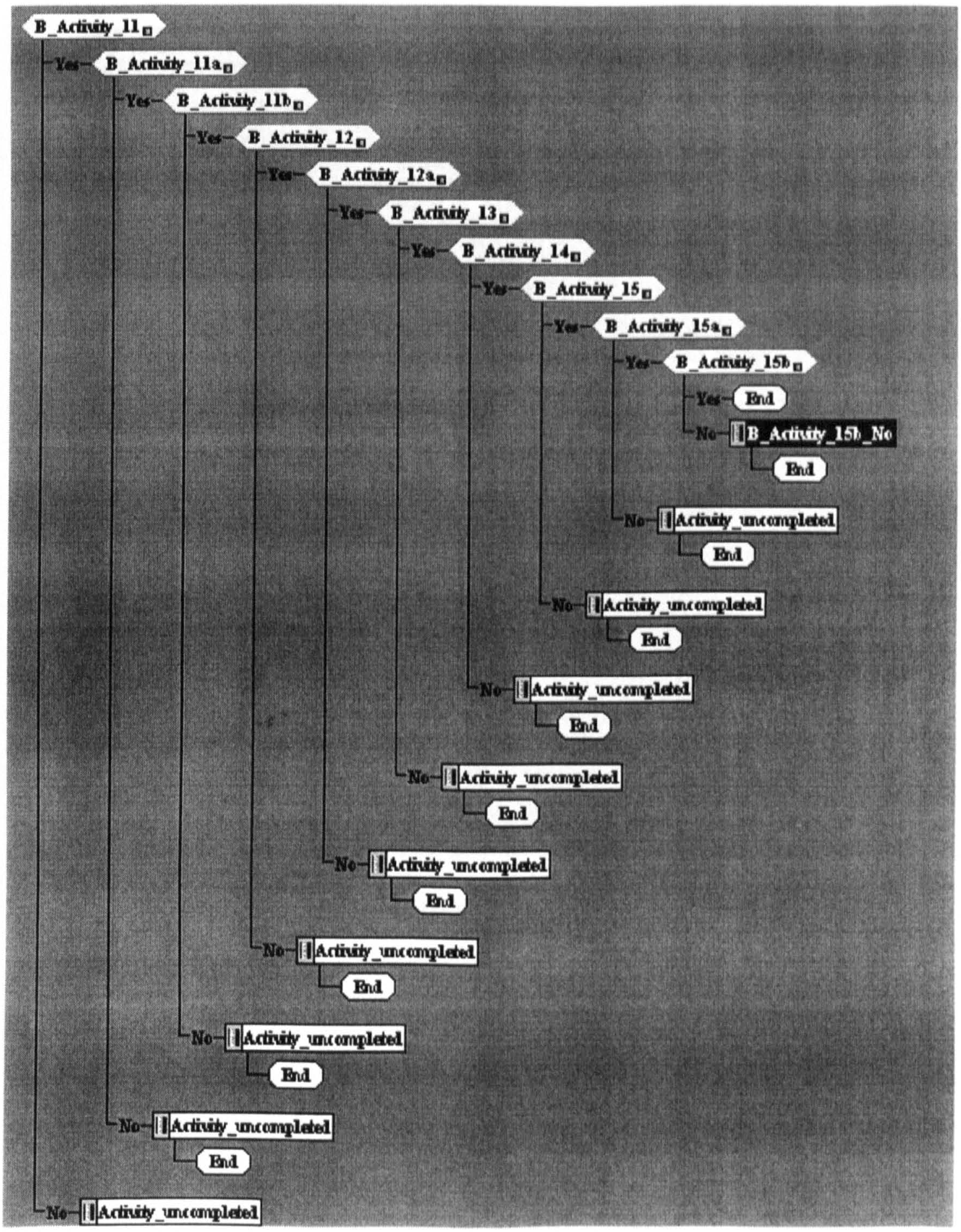


Figure 3.2 Decision tree of Stage B – Middle section (2)

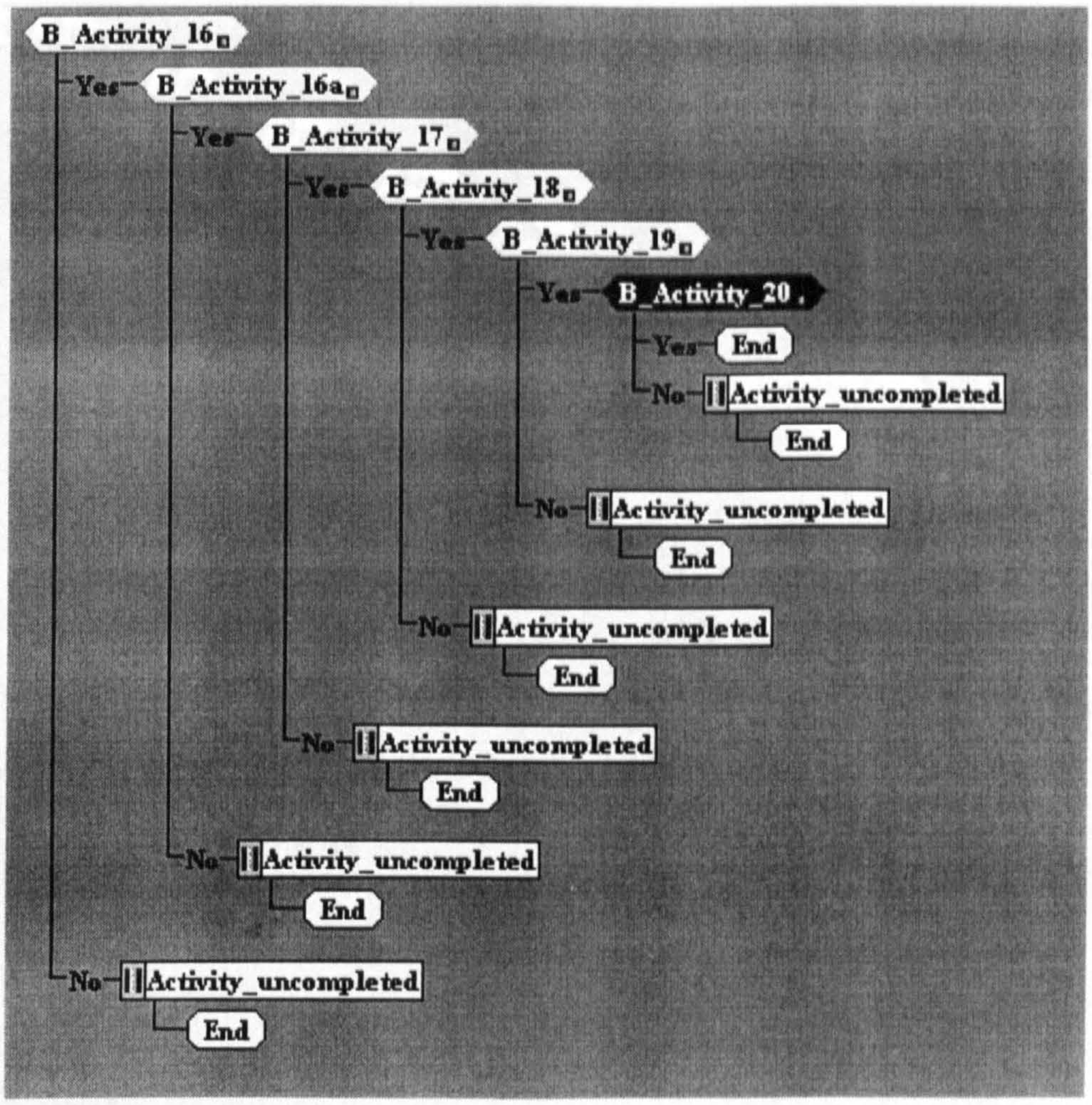


Figure 3.3 Decision tree of Stage B – Final section

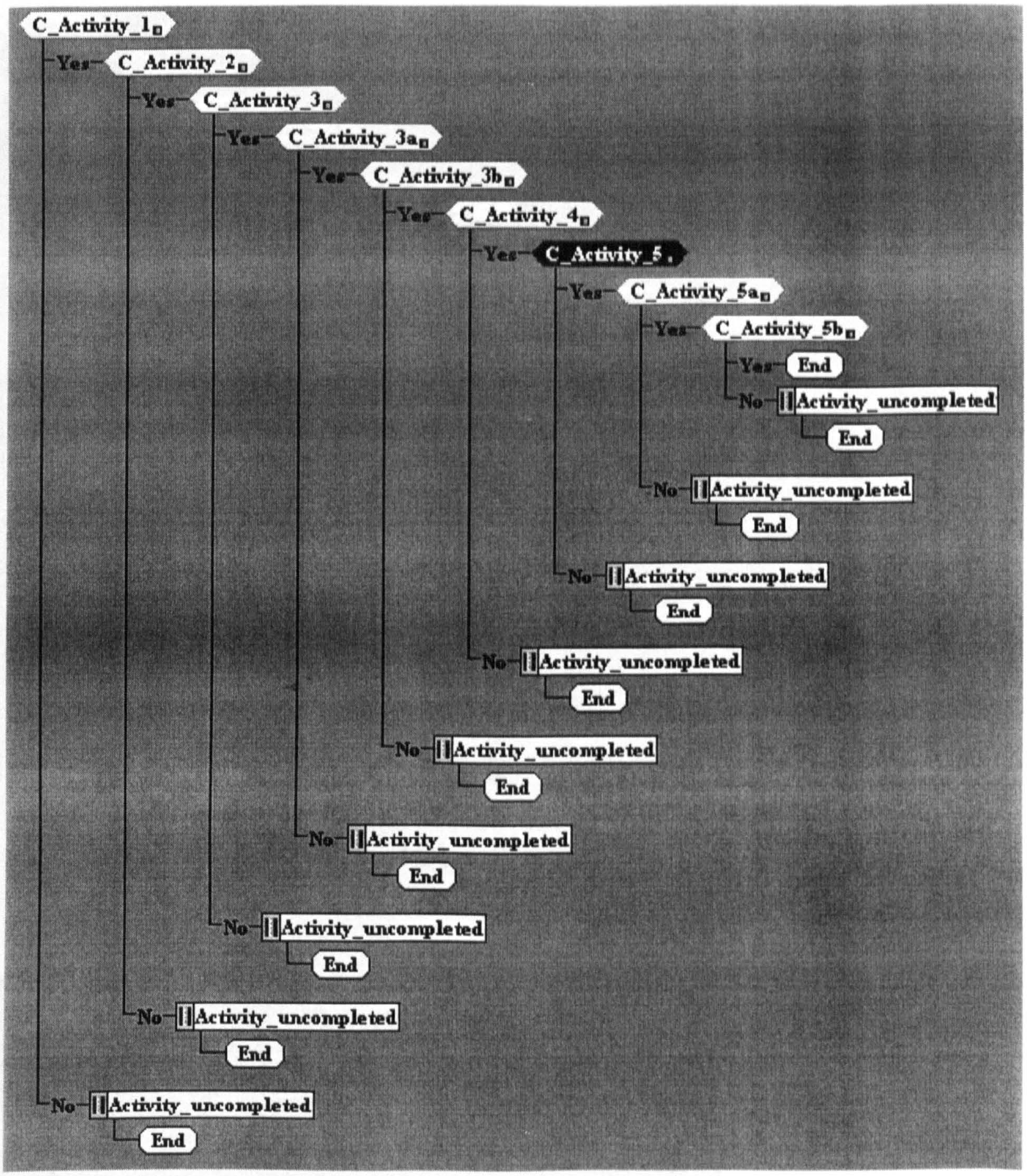


Figure 3.4 Decision tree of Stage C – Preliminary section

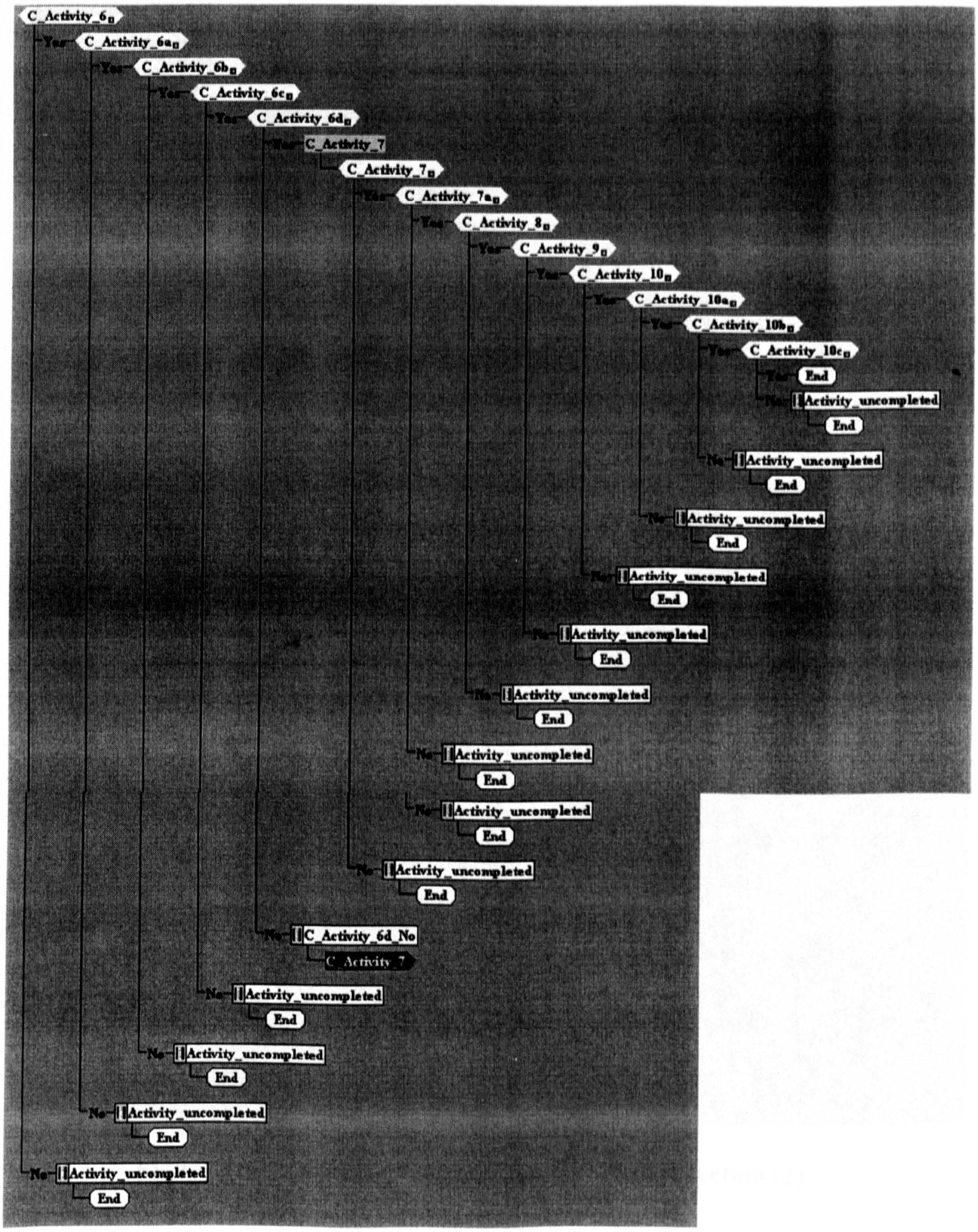


Figure 3.5 Decision tree of Stage C – Middle section (1)

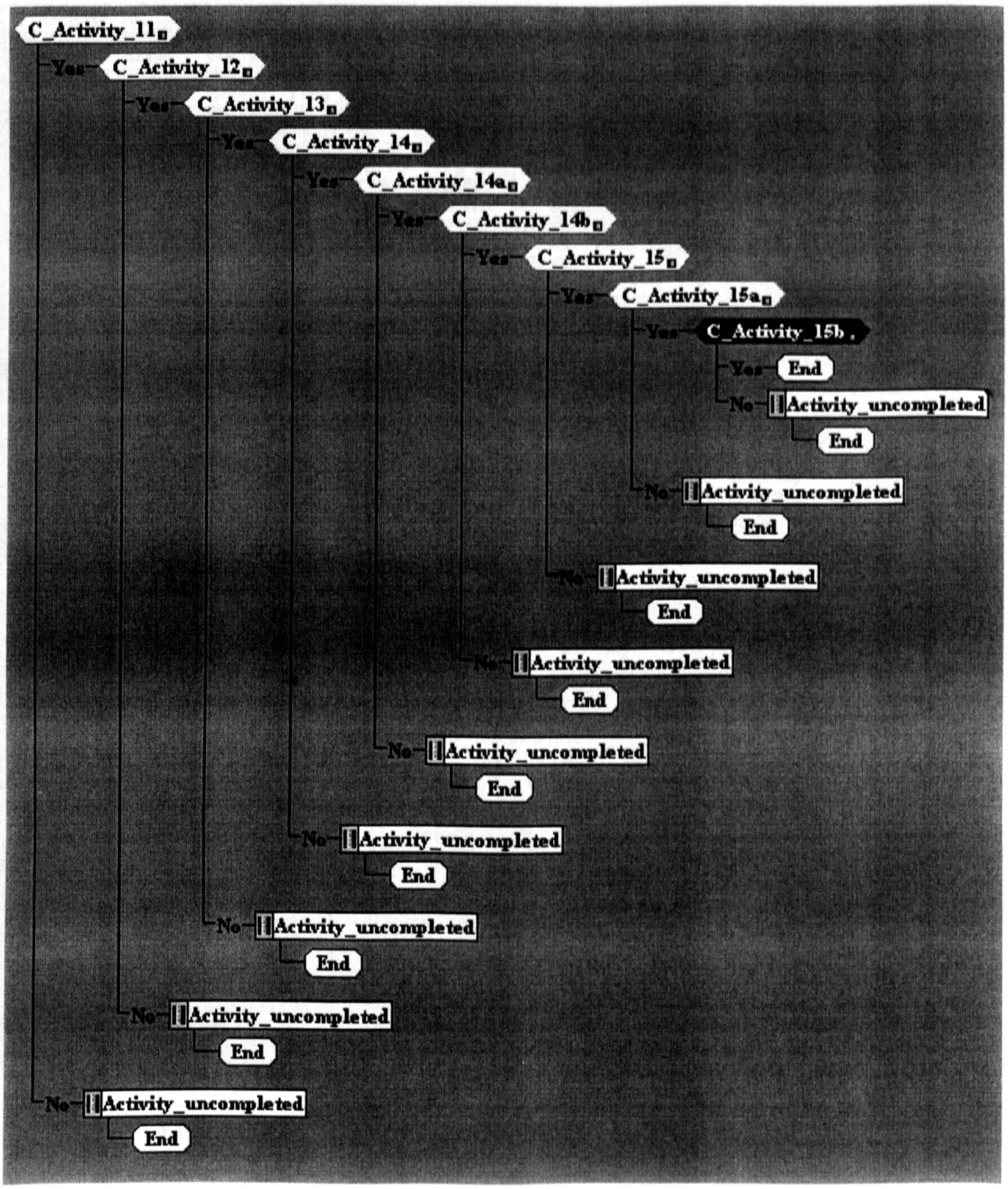


Figure 3.5 Decision tree of Stage C – Middle section (2)

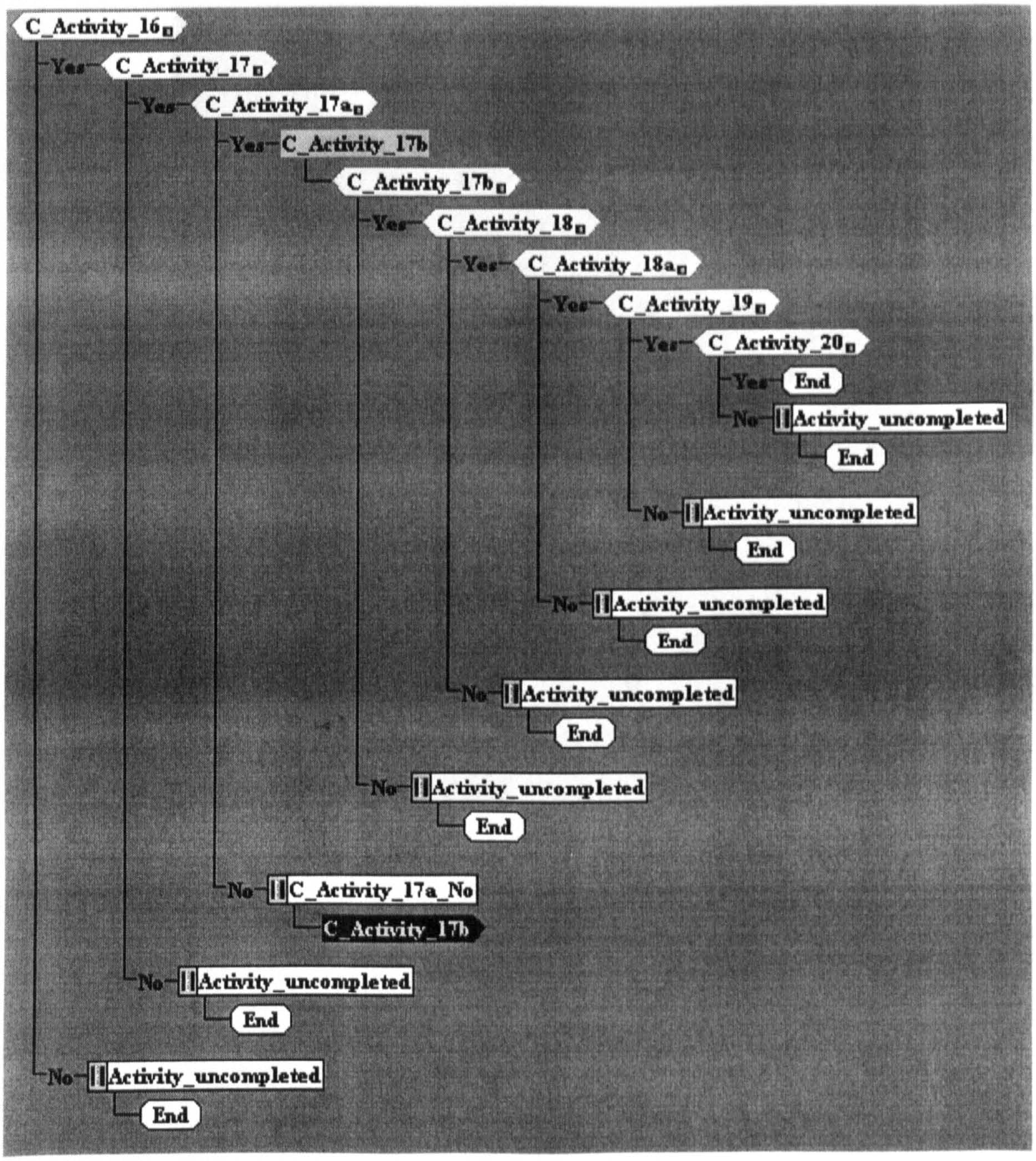


Figure 3.6 Decision tree of Stage C – Final section

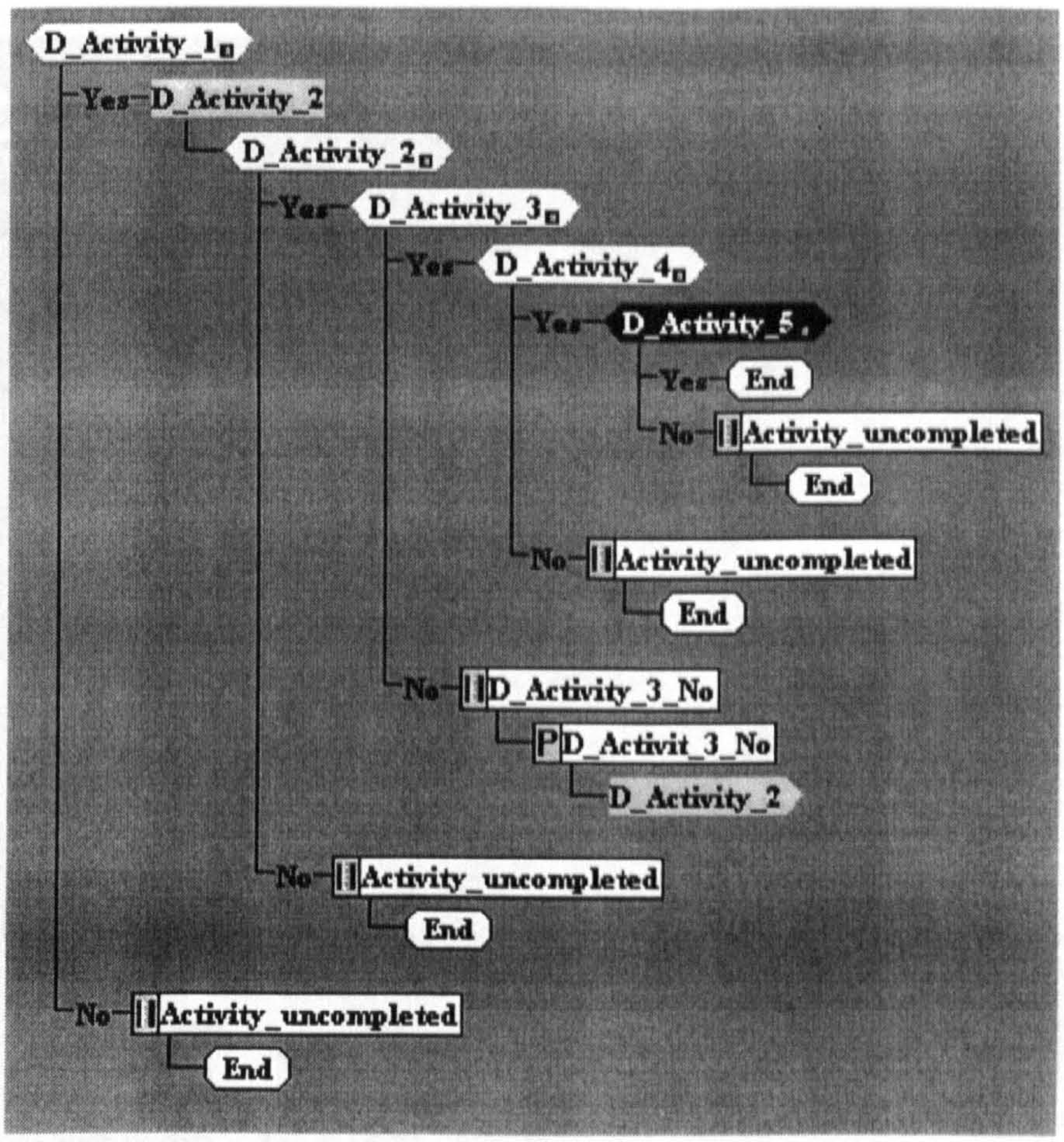


Figure 3.7 Decision tree of Stage D – Preliminary section

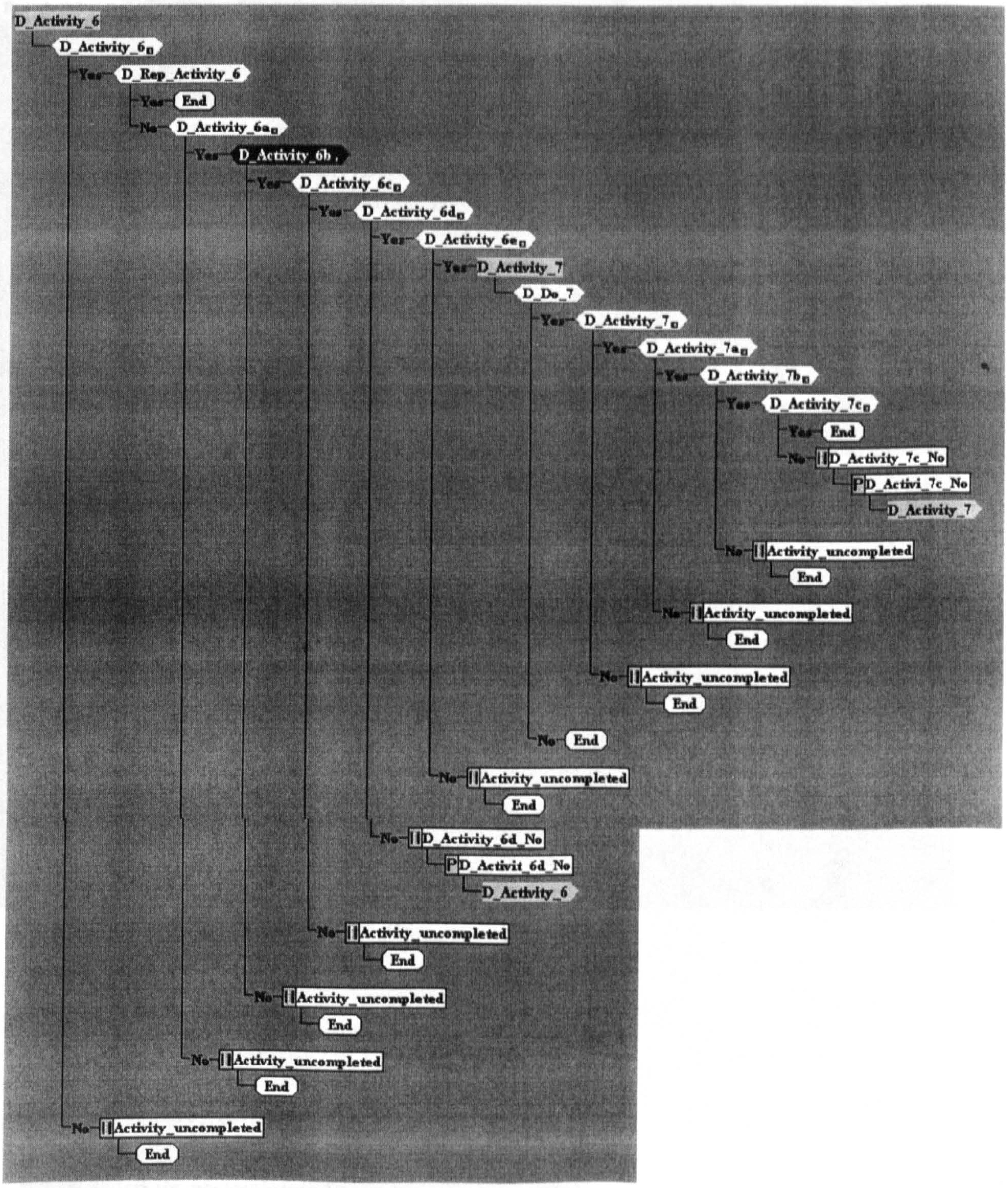


Figure 3.8 Decision tree of Stage D – Middle section (1)

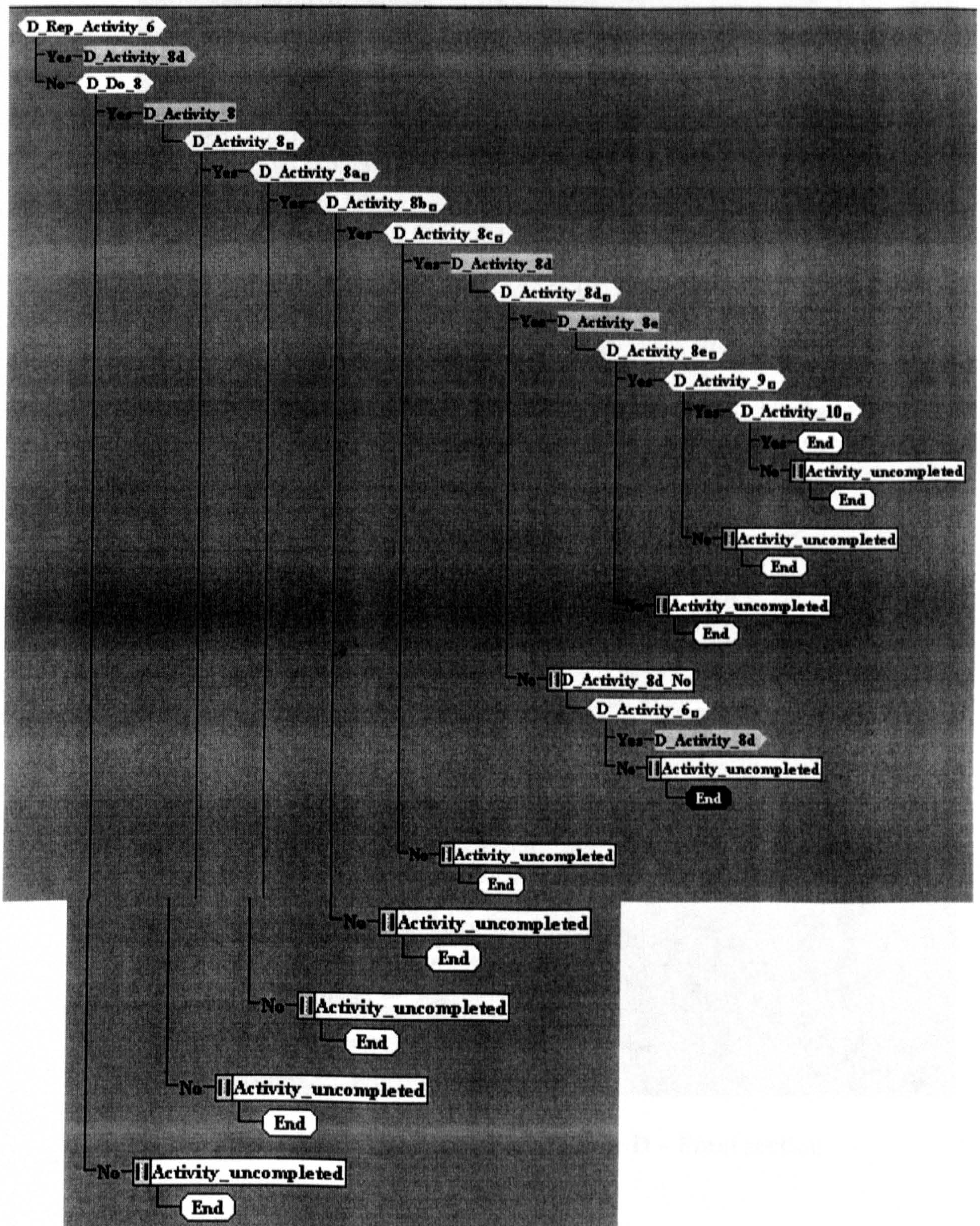


Figure 3.8 Decision tree of Stage D – Middle section (2)

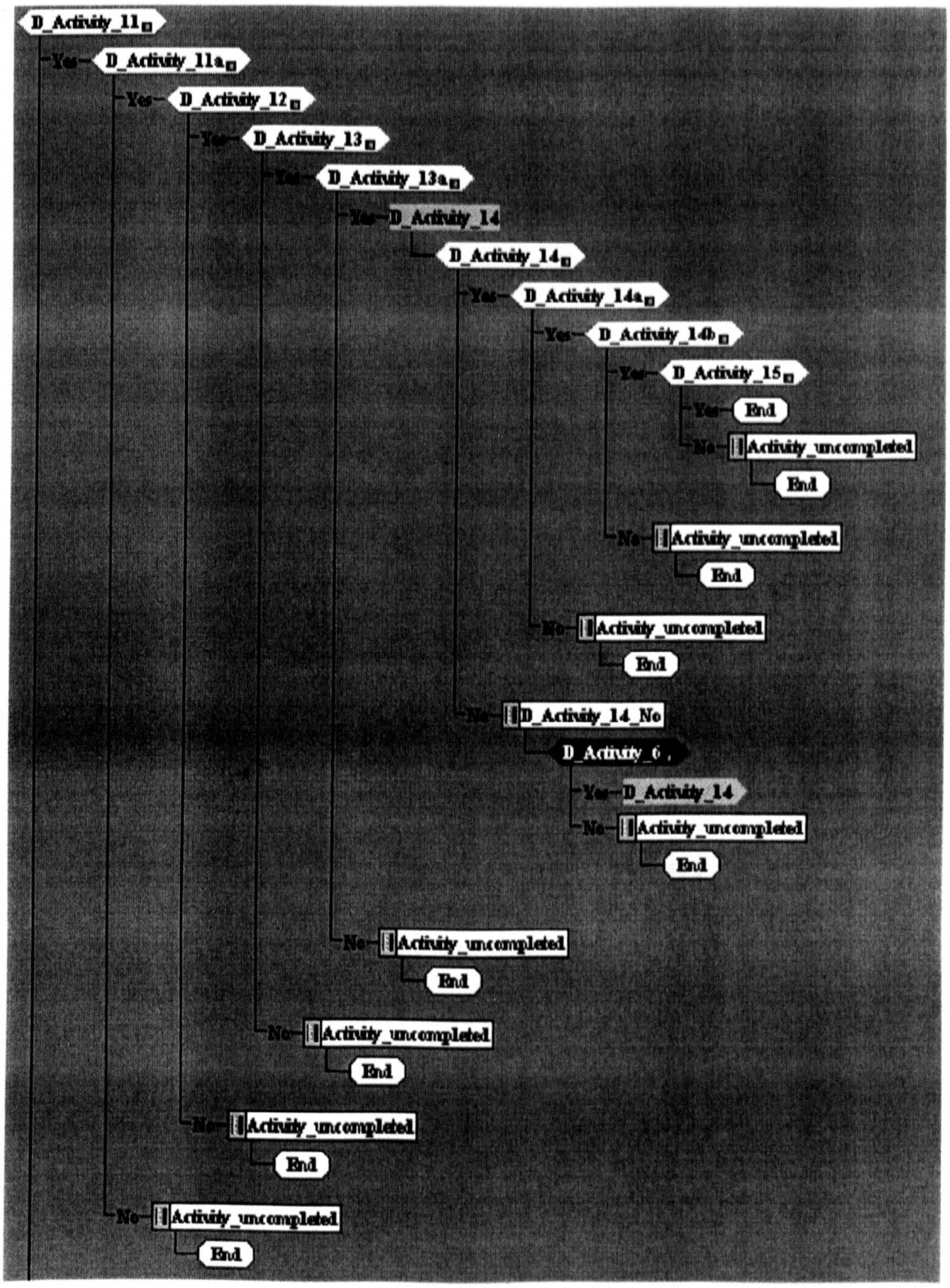


Figure 3.9 Decision tree of Stage D – Final section

Appendix 4

Information for first stage pilot survey

Letter to representatives from Housing Association at first stage of pilot survey

Managing Director
APKA HA Ltd.
13 Caldmore Green
Caldmore
Walshall
West Midlands
WS1 3RL

Date: 21 January 1999

Dear Sir/Madam,

Request for collaboration

I am a Ph.D. research student of the Built Environment Research Unit at the School of Engineering and the Built Environment, University of Wolverhampton.

My research topic is "Development of a process model for successful building projects". The primary aim of this project is to develop a model for the project manager or client representative to predict the likelihood of project success before the project begins. I intend to focus on the buildings developed by housing associations and I would be pleased if you would be ale to co-operate by completing a short questionnaire.

Could you give me some information on following questions?

1. Does your association usually use traditional design services for construction projects?
2. Does your association usually use the JCT 80 as the standard form QS construction contract?
3. Does your association employ an independent safety manager for construction projects?

I expect this model will be very useful and beneficial for the future success of projects and your kind help would be highly appreciated. Please feel free to contact me if there are any questions.

Thank you for your attention and kind assistance.

Yours faithfully,

Joanna Poon
Research Student
Built Environment Research Unit
School of Engineering and the Built Environment
University of Wolverhampton
Wolverhampton, WV1 1SB, UK
Tel: 01902-322108
Fax: 01902-322743
E-mail: e9817621@wlv.ac.uk

Reply form for representatives from Housing Association at first stage of pilot survey

Reply from APKA HA Ltd.

Name of respondent: ______________________________

Position: ______________________________

Tel. No.: ______________________________

Fax No.: ______________________________

		Yes	No
1.	This association usually use traditional design services for construction projects		
2.	This association usually uses the JCT 80 as the standard form QS construction contract?		
3.	This association employs an independent safety manager for construction projects.		
4.	I am willing to co-operate in completing a short questionnaire		

Appendix 5

Information for second stage pilot survey

Letter to representatives from Housing Association at second stage of pilot survey

Mr. C. M. Watson
Senior Development Officer
Leominister Marhces HA Ltd.
Lion Court
Broad Street
Leomominster
Herefordshire
HR6 8LE

Date: 14 April 1999

Dear Mr. Watson,

Request for comment a questionnaire

I am a Ph.D. research student of the Built Environment Research Unit at the School of Engineering and the Built Environment, University of Wolverhampton.

First, please let me to express my sincere gratitude for your kind assistance in returning my request for collaboration in February.

My research topic is "Development of a process model for successful building projects". The primary aim of this project is to develop a model for use by the project manager or client's representative in order to allow them predict the likelihood of project success before the project begins. This model is based on the traditional procurement route.

Could you please comment on the attached questionnaire? The description of diagrams and the guidance notes are also attached.

I expect this model will be very useful and beneficial for the future success of projects and your kind help would be highly appreciated. Please feel free to contact me if there are any questions.

Thank you for your attention and kind assistance

Yours faithfully,

Joanna Poon
Research Student
Built Environment Research Unit
School of Engineering and the Built Environment
University of Wolverhampton
Wolverhampton, WV1 1SB, UK
Tel: 01902-322108
Fax: 01902-322743
E-mail: e9817621@wlv.ac.uk

Reply form for representatives from Housing Association at second stage of pilot survey

Reply from Mr. C. M. Watson, Leominister Marhces HA Ltd

Part A

Please comment on the following aspects within the diagram

1. Are the critical issues describing each activity appropriate?
2. Are the project team members responsible for each activity appropriate?
3. Is the sequence of work in right order?
4. Is the description of each activity clear?
5. Have some activities been omitted?
6. Do you have any additional comment?

Part B

1. With which procurement strategy are you most familiarize, e.g. Traditional, Design and Build etc.?

____

____

2. Which standard form of contract do you use, e.g. JCT80 with quantities?

____

____

Attached explanatory note

Description of the diagram

The diagrams are based on the stages of works identified in the RIBA Plan of Work. Each recipient has been asked to comment on three stages only.

Description of first column

The first column identifies the critical issues within that construction stage. The critical issues include 'hotspot, time, cost, quality and safety.

H	-	Hotspot
T	-	Time
C	-	Cost
Q	-	Quality
S	-	Safety

The "hotspot" identifies the 'critical activities' within each stage of the project cycle to which each participant should pay special attention in order to ensure satisfactory performance before proceeding to next stage.

Description of second column

The second column identifies the participants in the construction process.

A	-	Architect
Q	-	Quantity Surveyor
Cl	-	Client
P	-	Planning Supervisor
Co	-	Contractor
SC	-	Sub-contractor
↓	-	Show the sequence of work

Description of third column

The third column shows the activities of the construction process, the numbers indicates the sequence of work.

Appendix 6

Information for major survey

Letters to new participants at major survey

Mr. Richard Taylor
Davis Langdon and Everest
29 Woodbourne Road
Harborne
Birmingham
B17 8BY

Date: 18 November 1999

Dear Mr. Taylor,

Request for interview

I am a Ph.D. research student in the Built Environment Research Unit at the School of Engineering and the Built Environment, University of Wolverhampton.

My research topic 'Development of a process model for successful building projects'. The aim of this project is to develop a system based on best practice, for use by the client's project manager. This can then be used to predict the likelihood of success on the building project. This model focuses on the traditional procurement strategy as it is the most popular procurement strategy but at the same time subject to most criticism.

The sub-aims of the project will be to develop a framework which clearly identifies the roles and responsibilities of the major parties on the building team and identifies the issues within the project cycle which can prove critical to project success viz. completion within time, cost, quality and safety.

Finally, the information will be incorporated into an expert system which can be used by future users before the start of their projects.

As this system has identified the roles and responsibilities of quantity surveyor, I would be pleased if you would be able to agree to have an interview.

In order to facilitate the discussion during the interview, I would like to send you some background information about my project. Could you please comment on the attached information and we have discussion later?

I expect this system will be very useful and beneficial for the future success of construction projects and your kind help would be highly appreciated. Please feel free to contact me if there are any questions.

Thank you for your attention and kind assistance.

Yours faithfully,
Joanna Poon
Research Student
Built Environment Research Unit
School of Engineering and the Built Environment
University of Wolverhampton
Wolverhampton, WV1 1SB, UK
Tel: 01902-322108
Fax: 01902-322743
E-mail: e9817621@wlv.ac.uk

Reply form for new participants at major survey

Reply from Mr. Richard Taylor, Davis Langdon and Everest

Name of respondent: ______________________________

Position: ______________________________

Tel. No.: ______________________________

Fax No.: ______________________________

Part A

Please comment on the following aspects within the diagram

1. Are the critical issues describing each activity appropriate?
2. Are the project team members responsible for each activity appropriate?
3. Is the sequence of work in right order?
4. Is the description of each activity clear?
5. Have some activities been omitted?
6. Do you have any additional comment?

Part B

Do you want to have an interview?

If so, could you please advise a date/ time that is convenient to be interviewed?

Letters to representatives from Housing Association at major survey

Mr. George Stoyan
Development Officer
South Shropshire HA Ltd.
111 Corve Street
Ludlow
Shropshire
SY9 1DJ

Date: 18 November 1999

Dear Mr. Stoyan,

Request for interview

I am a Ph.D. research student in the Built Environment Research Unit at the School of Engineering and the Built Environment, University of Wolverhampton.

First please let me to express my sincere gratitude for your kind assistance in returning my questionnaire in April 1999.

My research topic is 'Development of a process model for successful building projects'. The aim of this project is to develop a system based on best practice, for use by the client's project manager. This can then be used to predict the likelihood of success on the building project. This model focuses on the traditional procurement strategy as it is the most popular procurement strategy but at the same time subject to most criticism.

Finally, the information will be incorporated into an expert system which can be used by future users before the start of their projects.

Based on the comments that you give me last time, the prototype of this system has been developed. I would be pleased if you would be able to agree to have an interview.

In order to facilitate the discussion during the interview, I would like to send you some background information about my project. Could you please comment on the attached information and we have discussion later?

I expect this system will be very useful and beneficial for the future success of construction projects and your kind help would be highly appreciated. Please feel free to contact me if there are any questions.

Thank you for your attention and kind assistance

Yours faithfully,

Joanna Poon
Research Student
Built Environment Research Unit
School of Engineering and the Built Environment
University of Wolverhampton
Wolverhampton, WV1 1SB, UK
Tel: 01902-322108
Fax: 01902-322743
E-mail: e9817621@wlv.ac.uk

Reply form for representatives from Housing Association at major survey

Reply from Mr. George Stoyan, South Shropshire HA Ltd.

Part A

Please comment on the following aspects within the diagram

1. Are the critical issues describing each activity appropriate?
2. Are the project team members responsible for each activity appropriate?
3. Is the sequence of work in right order?
4. Is the description of each activity clear?
5. Have some activities been omitted?
6. Do you have any additional comment?

Part B

Do you want to have an interview?

If so, could you please advise a date/ time that is convenient to be interviewed?

Explanation of the attached information

This folder contains two sets of information.

The first set is the flowchart diagram, which lists the sequence of activities. The description of the flowchart diagram is attached.

The second set is the introduction information that is contained in the expert system.

Information Set One

Description of the flowchart diagram

The diagrams are based on the stages of works identified in the RIBA Plan of Work. The information in the first four stages, from Inception to Scheme Design, has been sent out.

Description of first column

The first column identifies the critical issues within that construction stage. The critical issues include 'hotspot, time, cost, quality and safety.

H - Hotspot
T - Time
C - Cost
Q - Quality
S - Safety

The "hotspot" identifies the 'critical activities' within each stage of the project cycle to which each participant should pay special attention in order to ensure satisfactory performance before proceeding to next stage.

Description of second column

The second column identifies the participants in the construction process.

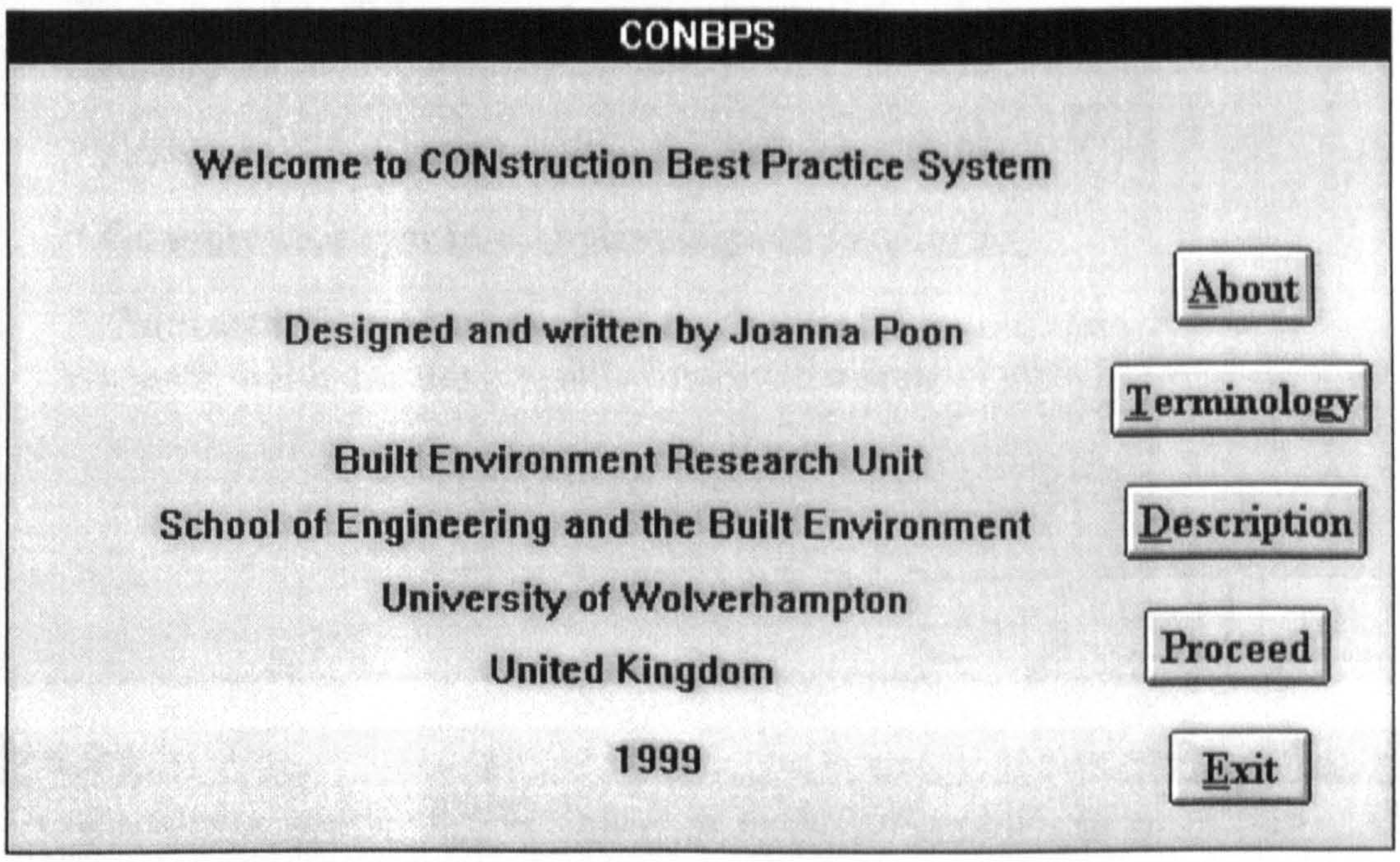
A - Architect
Q - Quantity Surveyor
Cl - Client
P - Planning Supervisor

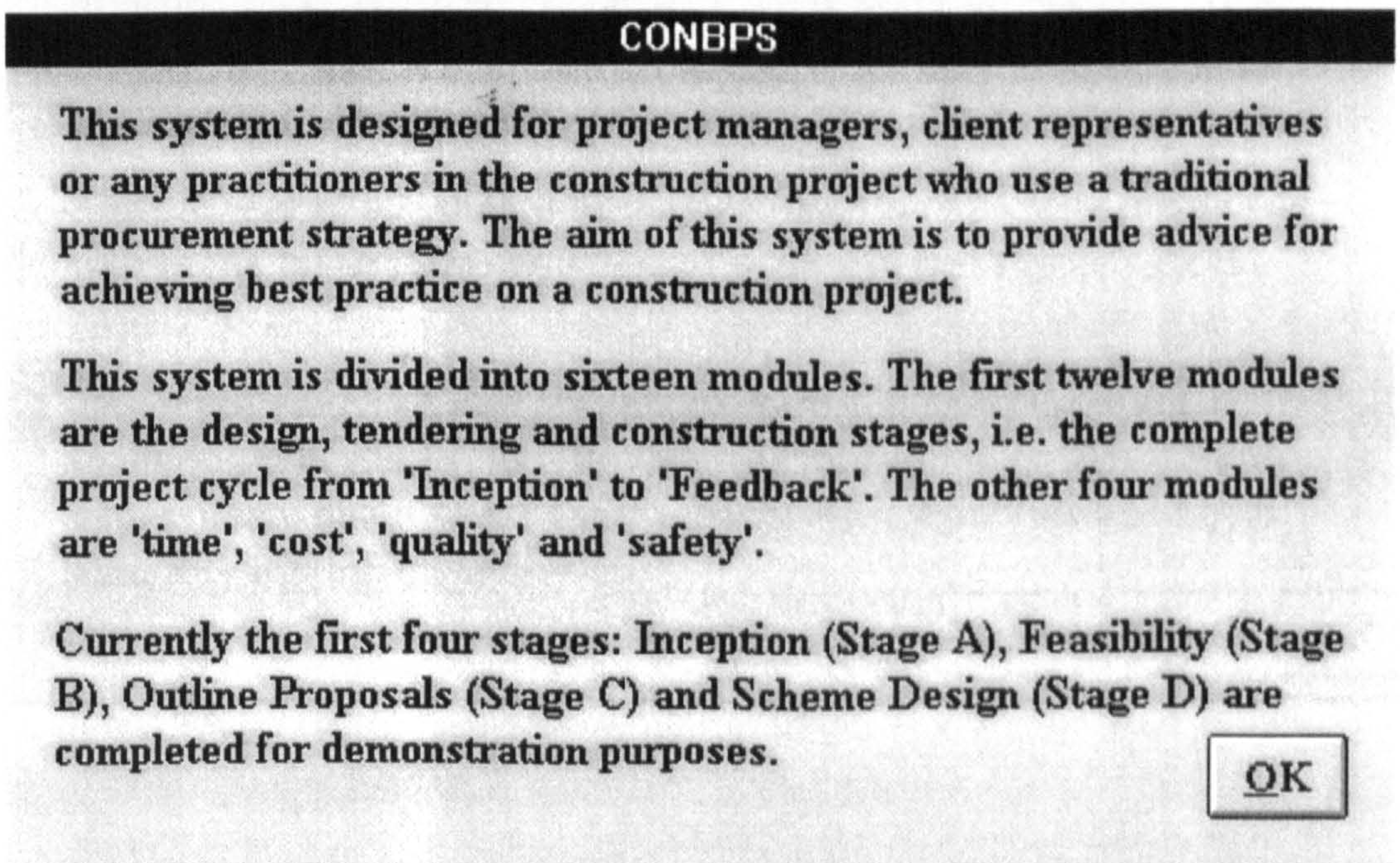
↓ - Show the sequence of work

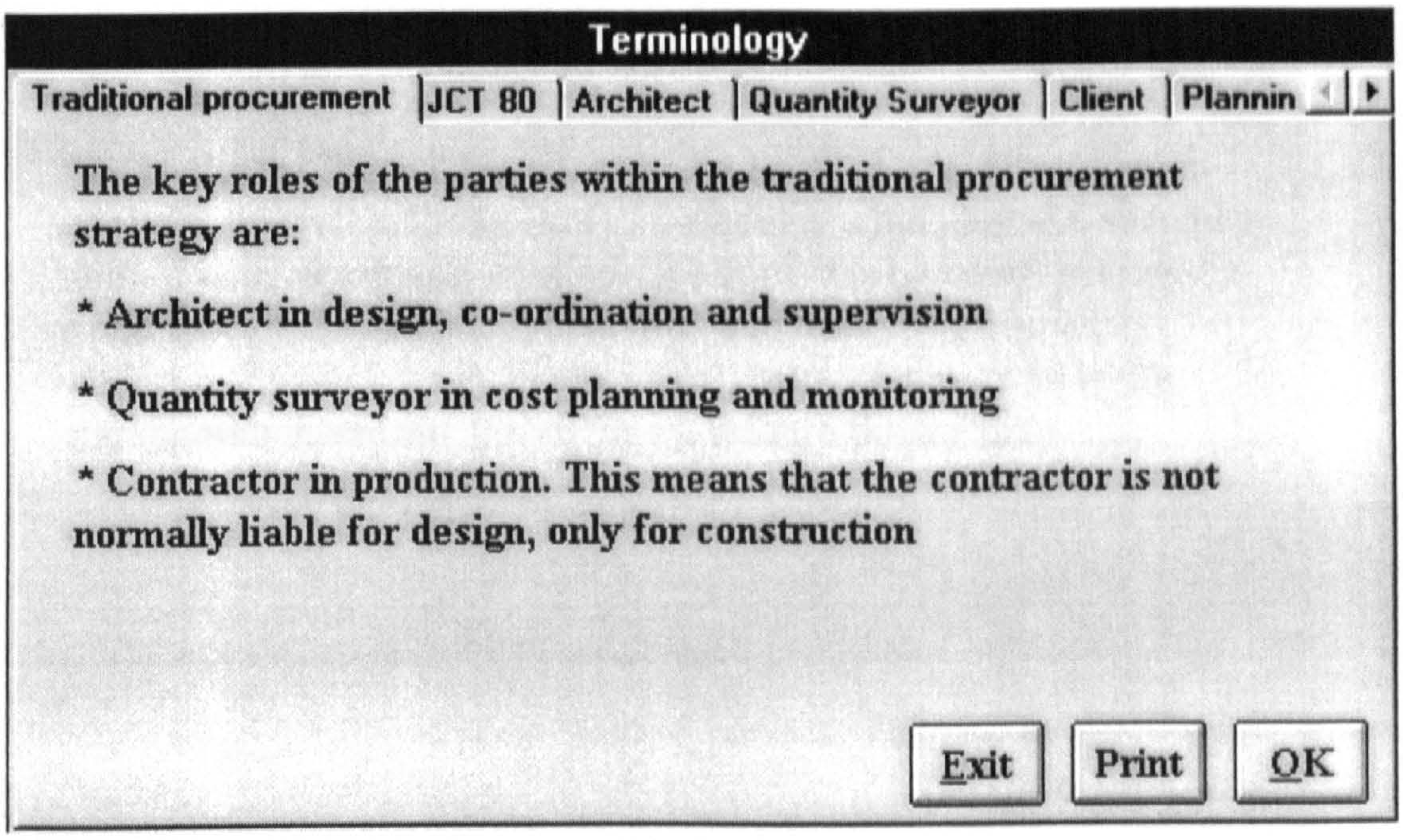
Description of third column

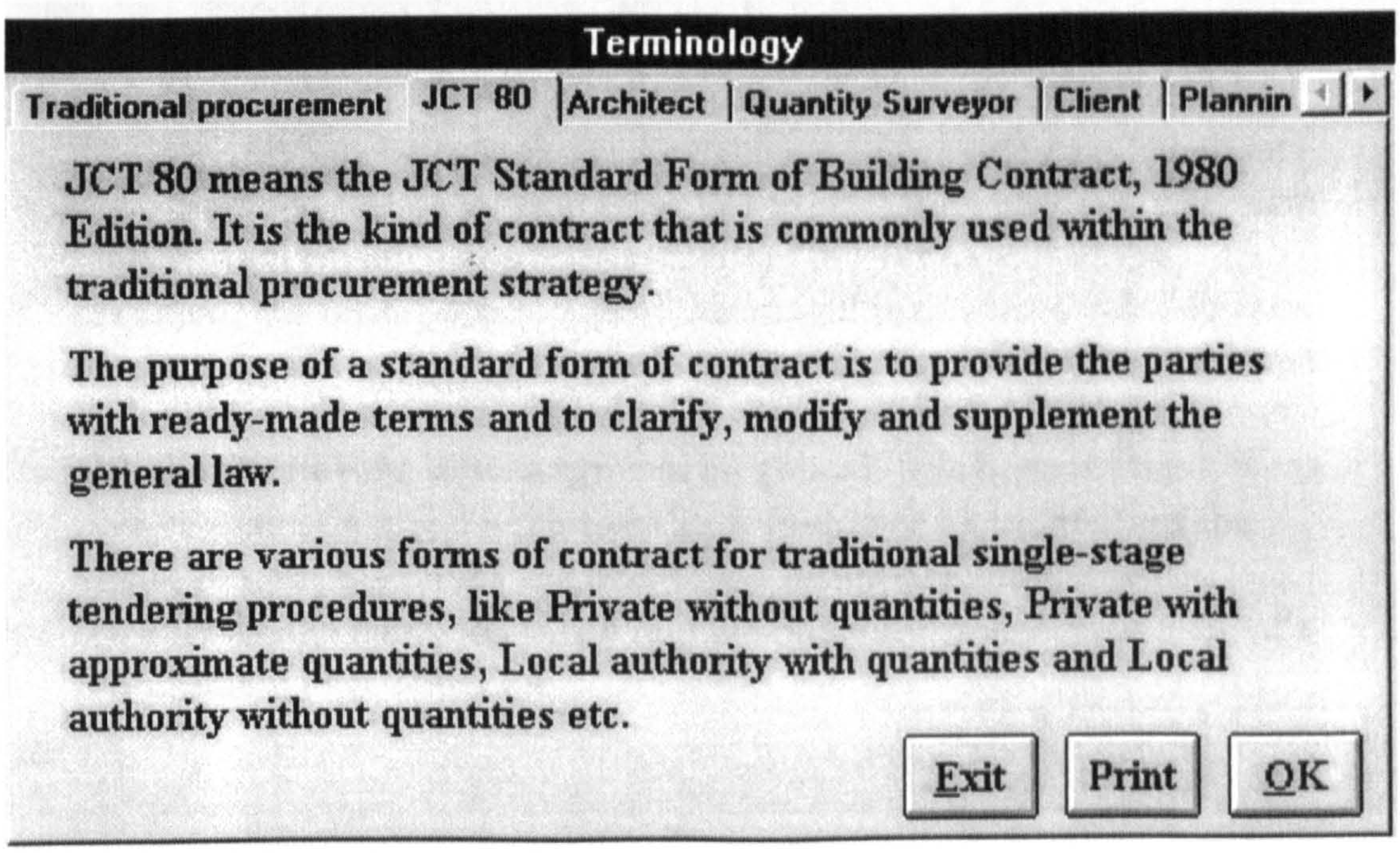
The third column shows the activities of the construction process, the numbers indicates the sequence of work.

Information Set Two






Terminology
Traditional procurement
JCT 80
Architect
Quantity Surveyor
Client
Plannin
The key roles of the parties within the traditional procurement strategy are:
* Architect in design, co-ordination and supervision
* Quantity surveyor in cost planning and monitoring
* Contractor in production. This means that the contractor is not normally liable for design, only for construction
Exit
Print
OK


Terminology
Traditional procurement
JCT 80
Architect
Quantity Surveyor
Client
Plannin
JCT 80 means the JCT Standard Form of Building Contract, 1980 Edition. It is the kind of contract that is commonly used within the traditional procurement strategy.
The purpose of a standard form of contract is to provide the parties with ready-made terms and to clarify, modify and supplement the general law.
There are various forms of contract for traditional single-stage tendering procedures, like Private without quantities, Private with approximate quantities, Local authority with quantities and Local authority without quantities etc.
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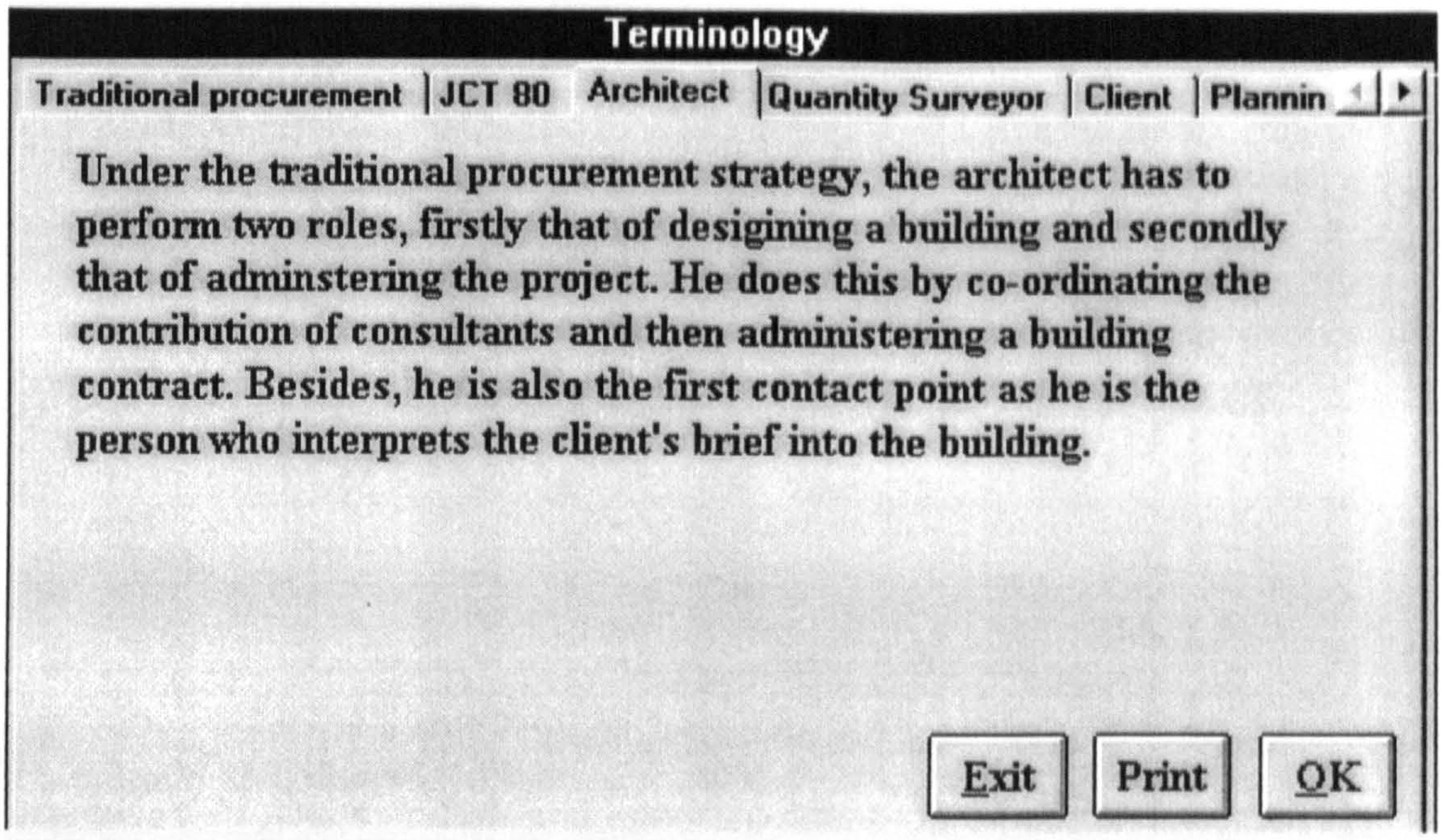
Terminology
Traditional procurement
JCT 80
Architect
Quantity Surveyor
Client
Plannin
Under the traditional procurement strategy, the architect has to perform two roles, firstly that of desigining a building and secondly that of adminstering the project. He does this by co-ordinating the contribution of consultants and then administering a building contract. Besides, he is also the first contact point as he is the person who interprets the client's brief into the building.
Exit
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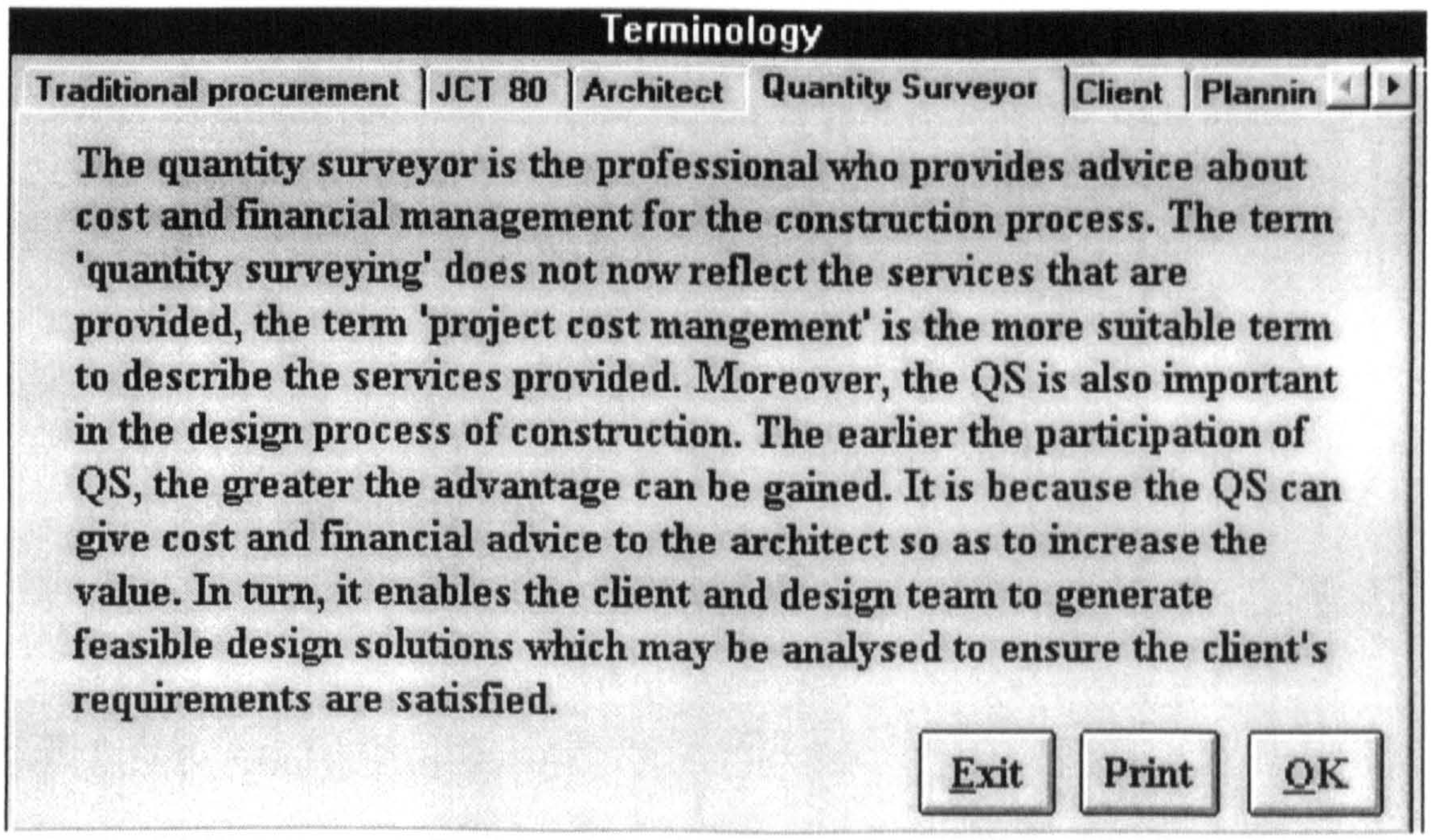
OK


Terminology
Traditional procurement
JCT 80
Architect
Quantity Surveyor
Client
Plannin
The quantity surveyor is the professional who provides advice about cost and financial management for the construction process. The term 'quantity surveying' does not now reflect the services that are provided, the term 'project cost mangement' is the more suitable term to describe the services provided. Moreover, the QS is also important in the design process of construction. The earlier the participation of QS, the greater the advantage can be gained. It is because the QS can give cost and financial advice to the architect so as to increase the value. In turn, it enables the client and design team to generate feasible design solutions which may be analysed to ensure the client's requirements are satisfied.
Exit
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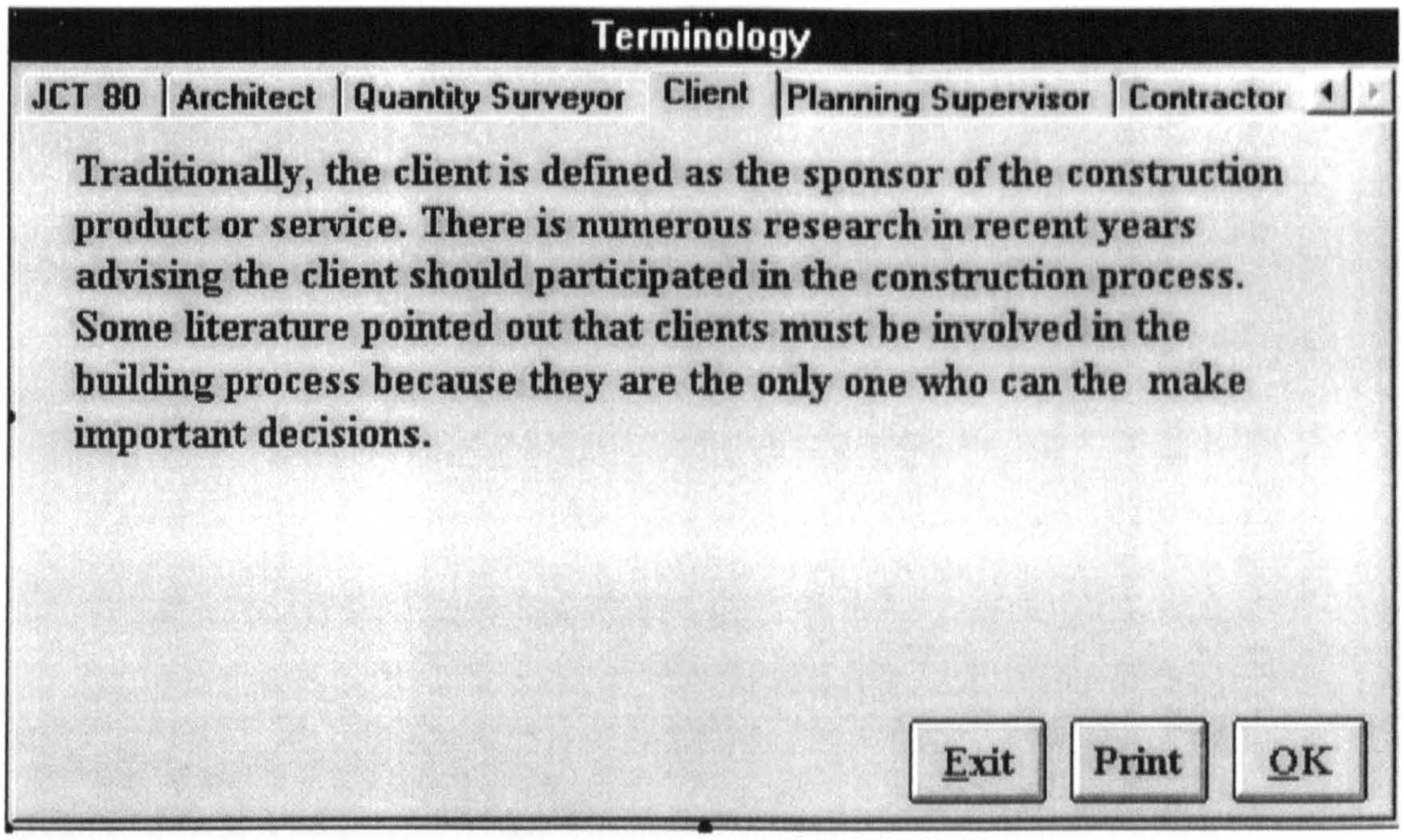
OK


Terminology
JCT 80
Architect
Quantity Surveyor
Client
Planning Supervisor
Contractor
Traditionally, the client is defined as the sponsor of the construction product or service. There is numerous research in recent years advising the client should participated in the construction process. Some literature pointed out that clients must be involved in the building process because they are the only one who can the make important decisions.
Exit
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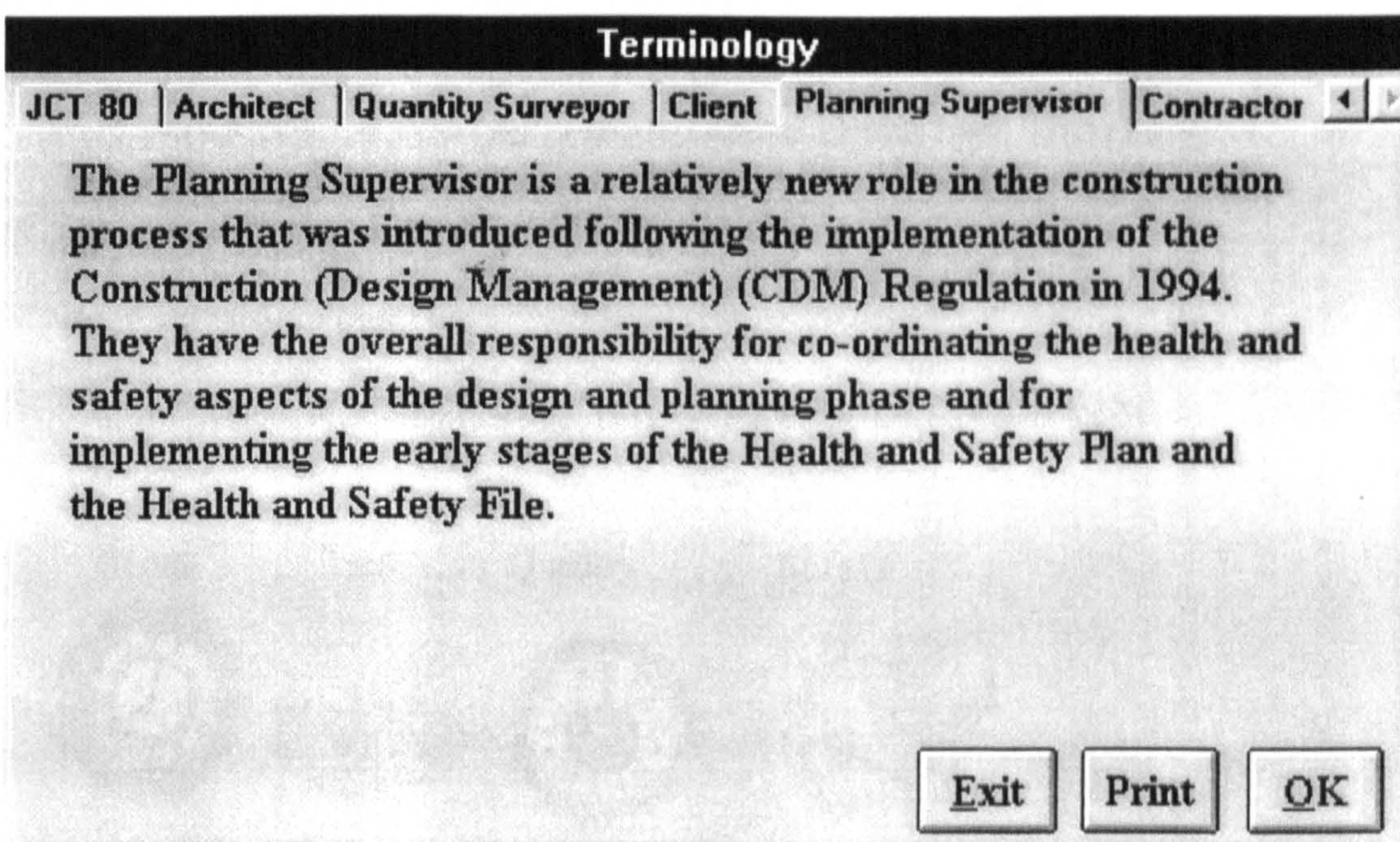

Terminology
JCT 80
Architect
Quantity Surveyor
Client
Planning Supervisor
Contractor
The Planning Supervisor is a relatively new role in the construction process that was introduced following the implementation of the Construction (Design Management) (CDM) Regulation in 1994. They have the overall responsibility for co-ordinating the health and safety aspects of the design and planning phase and for implementing the early stages of the Health and Safety Plan and the Health and Safety File.
Exit
Print
OK

Terminology

JCT 80 | Architect | Quantity Surveyor | Client | Planning Supervisor | Contractor

Under the traditional contracting strategy, the level of participation of the contractor is lower than in other procurement strategies. The contractor will not participate in the project until estimating the prices for the Bills of Quantities and they are obliged to build what the archtiect has documented.

Exit | Print | OK

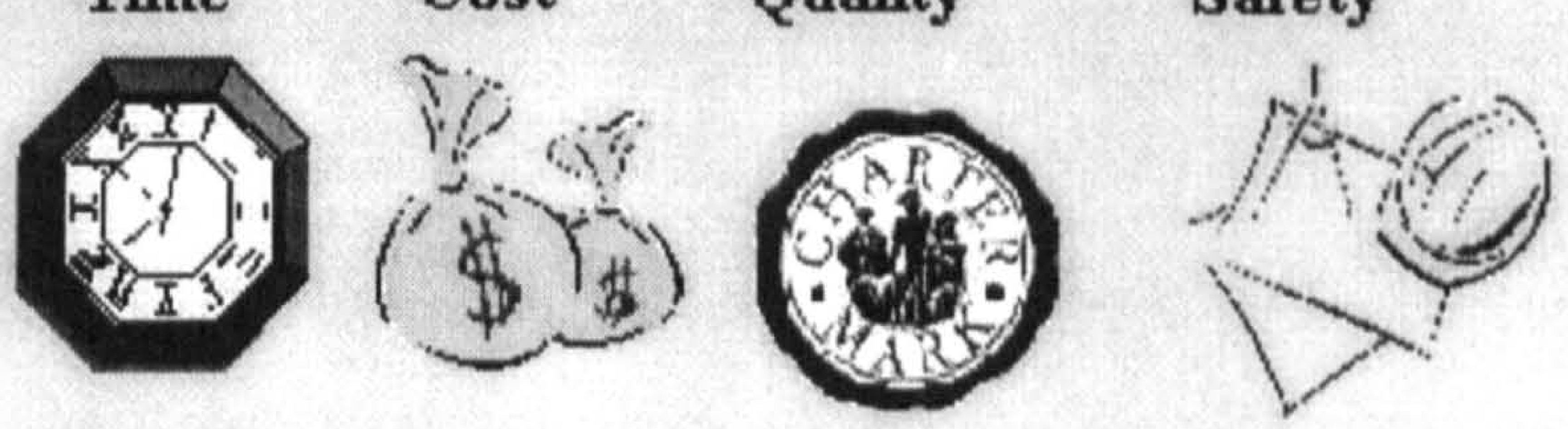
Description of CONBPS

Each construction activity is represented in one box. The relevant party within that activity will be identified in CAPITAL LETTERS.

If certain activity critical or is a 'hotspot', the whole sentence will become red colour.

The criteria for each activity will also be stated in each box. Symbols will be used to represent the criteria:

Time Cost Quality Safety

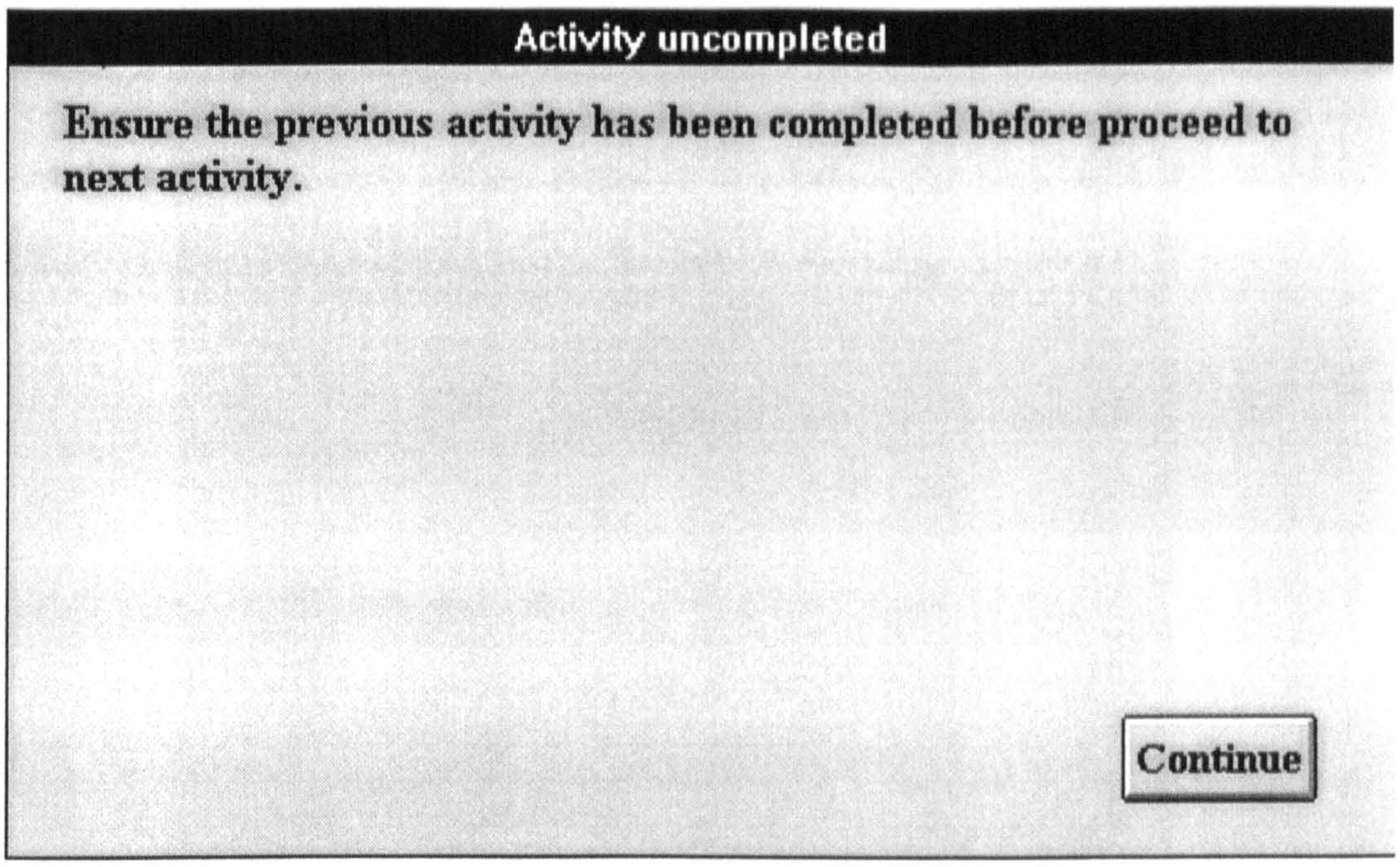


Apart from stating the activities, the model also contains two columns which are 'information' and awareness'.

The 'information' column identifies the important terminology and information.

The 'awareness' column identifies the key areas for consideration and what can happen if the participants do not complete the activity.

OK


Activity uncompleted
Ensure the previous activity has been completed before proceed to next activity.
Continue

Appendix 7

Theoretical framework for updated CONBPS

Stage B : Feasibility

Criteria		Activities	Note
Q	1	Update project brief (based on preliminary project study)	CA
T C Q	2	Update project execution plan	CA
T	3	Update process execution plan	CA
	4	Plan and co-ordinate the feasibility study	
Q	5	Carry out feasibility studies	
H	5a	Prepare and maintain master cost plan	Sub
T C Q	5b	Prepare site investigation	Sub
T C Q	5c	Carry out site study	Sub
C	6	Provide cost advice	CA
C	6a	Prepare initial budget estimate	Sub/CA
C	6b	Check the cost effectiveness of the project	Sub/CA
Q	7	Receive feasibility report and discuss with project manager	
Q	8	Prepare final feasibility report to client	
Q	9	Final review on feasibility report	
T	10	Decide to abandon, continue or modify the project	
S	11	Prepare Health and Safety Plan	CA
T C Q	12	Identify risk management issues	CA
T C Q	13	Prepare value management concept for the project	CA
T C Q	14	Prepare Environment Impact Assessment (EIA)	CA
C	15	Prepare cost plan	CA
C	15a	Prepare estimates of running costs (maintenance, staffing etc.)	Sub/CA
C	15b	Prepare budget statement	Sub/CA
T C Q	16	Identify design management issues	CA
Q	16a	Give advice on outline design plan	Sub/CA
Q	16b	Investigation of main services supplies	Sub/CA
Q	16c	Provide services in connection with environmental issues	Sub/CA
Q	16d	Work on initial design and test against planning control and constraints of costs, structure and services	Sub/CA
Q	17	Preparing zoning and strategic layouts	

If decide abandon, no need to proceed.
If decide to modify, please go back to appropriate activity

Stage B : Feasibility

Project Manager	Architect	Quantity Surveyor	Structural Engineer	Service Engineer	Planning Supervisor	Client
1M	1A	1A	1A	1A		
2M	2A	2A	2A	2A		
3M	3A	3A	3A	3A		
4M	4A	4A	4A	4A		
5M 6A	5A 6A	5A 6M	5A 6A	5A 6A		
5aA 6aA	5aA 6aA	5aM 6aM	5aA 6aA	5aA 6aA		
5bA 6bA	5bA 6bA	5bA 6bM	5bM 6bA	5bA 6bA		
5cA	5cA	5cA	5cM	5cA		
7A						7M
8M						8A
9M						9A
10A						10M
11M 12M 13M 14M	11A 12A 13A 14A	11A 12A 13A 14A	11A 12A 13A 14A	11A 12A 13A 14A	11A 12A 13A 14A	11A 12A 13A 14A
15A	15A	15M	15A	15A		
15aA	15aA	15aM	15aA	15aA		
15bA	15bA	15bM	15bA	15bA		
16A	16M	16A	16A	16A	16A	
16aA	16aM	16aA	16aA	16aA		
				16bM		
				16cM		
16dA	16dM	16dA	16dA	16dA		
	17M	18M	19M	20M		
21M	21A	21aM	21A	21A		
22M	22A 22aM	22bM	22A	22A	22A	
23M	23A	23A	23A	23A		
24A	24M	24A	24A	24A		

Stage C : Outline Proposals

Criteria	Activities		Note
H	1	Update project brief	CA
T C Q	2	Update Project Execution Plan	CA
T	3	Update Process Execution Plan	CA
Q	4	Study and analyse similar projects and visit them	
Q	5	Incorporate TQM concept in the outline proposal	
C	6	Update value management issues in the outline proposal	CA
S	7	Update Health and Safety Plan	CA
Q	8	Co-ordinate with consultants about development of conceptual plans	
Q	8a	Develop design	Sub
Q	8b	Define structural layout	Sub
C	9	Continue the development of cost plan	
Q	10	Define means of escape and compartments	
C Q	11	Prepare cost studies for detailed design	
Q	12	Refine structural layout to accommodate compartmentation and services zoning	
T	13	Update the application process to the planning authorities	CA
C	14	Update cost plan and cost checking	CA
Q	15	Prepare design and co-ordiante with building elements	
Q	16	Refine major plant areas and builder's work requirements	
Q	17	Prepare material and construction specification	
Q	18	Prepare final room layouts	
C	19	Check cost of design against cost plan and prepare reconciliation	
C	20	Finalise cost plan	
H	21	Finish project proposal	

Stage C : Outline Proposals

Project Manager	Architect	Quantity Surveyor	Structural Engineer	Service Engineer	Planning Supervisor	Client
1M	1A	1A	1A	1A		1A
2M	2A	2A	2A	2A		
3M	3A	3A	3A	3A		
4M	4A	4A	4A	4A		
5M	5A	5A	5A	5A		
6M	6A	6A	6A	6A		
7A	7A	7A	7A	7A	7M	
8M	8aM		8bM			
9A	9A	9M	9A	9A		
	10M 12A	11M	12M			
13M	13A		13A	13A		
	15M	14M		16M		
17A	17M	17A	17A	17A		
18A	18M		18A	18A		
	19M					
20A	20A	20M	20A	20A		
21M	21A					

Stage D : Scheme Design

Criteria	No.	Activities	Note
H	1	Update project brief	CA
T C Q	2	Update project execution plan	CA
T	3	Update process execution plan	CA
H	4	Establish procedures for checking compliance with designs and specification	
T C Q	5	Update concept design	CA
T C Q	6	Update procurement plan (supply management)	CA
S	7	Update Health and Safety Plan	CA
T C Q	8	Update value management issues	CA
T C Q	9	Update EIA in scheme design proposal	CA
C	10	Update cost plan	CA
C	10a	Develop cost forecasting	Sub
Q	10b	Update estimate of revenue costs	Sub
Q	10c	Check design against cost plan	Sub/CA
Q	11	Update design management issues	CA
T C Q	11a	Refine structural layout to accommodate compartmentation and services zoning	Sub
Q	11b	Prepare design and co-ordinate with building elements	Sub
Q	11c	Co-ordinate plans including user outlets and all terminals	Sub
T C Q	11d	Prepare material and construction specification	Sub
Q	11e	Review scheme design drawings	Sub
Q	11f	Co-ordinate with consultants for the preparation of design brief	Sub
T	12	Ensure that all application for statutory approvals are made	
T	12a	Co-ordinate statutory submissions to obtain approvals	Sub
H	13	Report consultant scheme design proposals to Client	
T C Q	13a	Oversee the design process and monitor whether the deliverables are produced on time and identify any potential changes	Sub
Q	13b	Co-ordinate the submission of the design	Sub
C Q	14	Start to prepare tenderer list and tender document	
C Q	14a	Provide input to and and monitor the production of tender documents	Sub
T C	14b	Update risk assessment for preparing tender documents	Sub/CA
C	14c	Prepare pre-tender estimate and update budget costs	Sub/CA

Stage D: Scheme Design

Project Manager	Architect	Quantity Surveyor	Structural Engineer	Service Engineer	Planning Supervisor	Client
1M	1A	1A	1A	1A		1A
2M	2A	2A	2A	2A		
3M	3A	3A	3A	3A		
4A	4M					
5A	5M	5A	5A	5A		
6M	6A	6A	6A	6A		
7A	7A	7A	7A	7A	7M	
8A	8A	8M	8A	8A		
9M	9A	9A	9A	9A		
10A	10A	10M	10A	10A		
10aA	10aA	10aM	10aA	10aA		
10bA	10bA	10bM	10bA	10bA		
10cA	10cM	10cA	10cA	10cA		
10dA	10dA	10dM	10dA	10dA		
11A	11M	11A	11A	11A		
	11aA		11aM	11aA		
	11bM	11bA	11bA	11bA		
	11cM			11cA		
11dA	11dM	11dA	11dA	11dA		
11eA	11eM	11eA	11eA	11eA		
11fA	11fM					
12M	12A	12A	12A	12A		
12aM	12aA	12aA	12aA	12aA		
	13M					13A
13aM	13aA					
13bM	13bA					
14bM	14bA	14bA	14bA	14bA		
14cA	14cA	14cM	14cA	14cA		

Appendix 8

Screens of the file 'Intro' of updated CONBPS

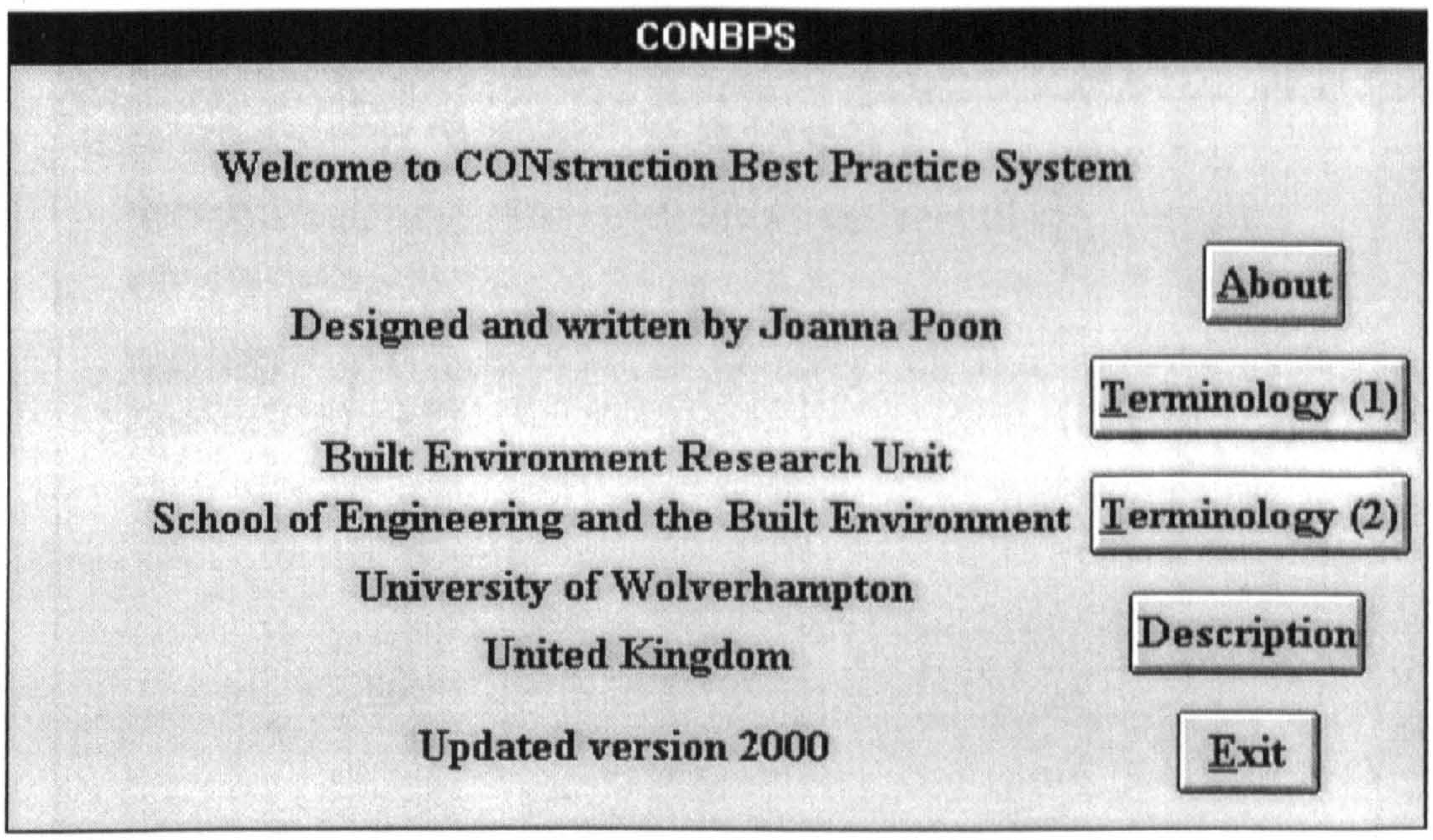


Figure 8.1 Introductory screen of 'Introduction' file

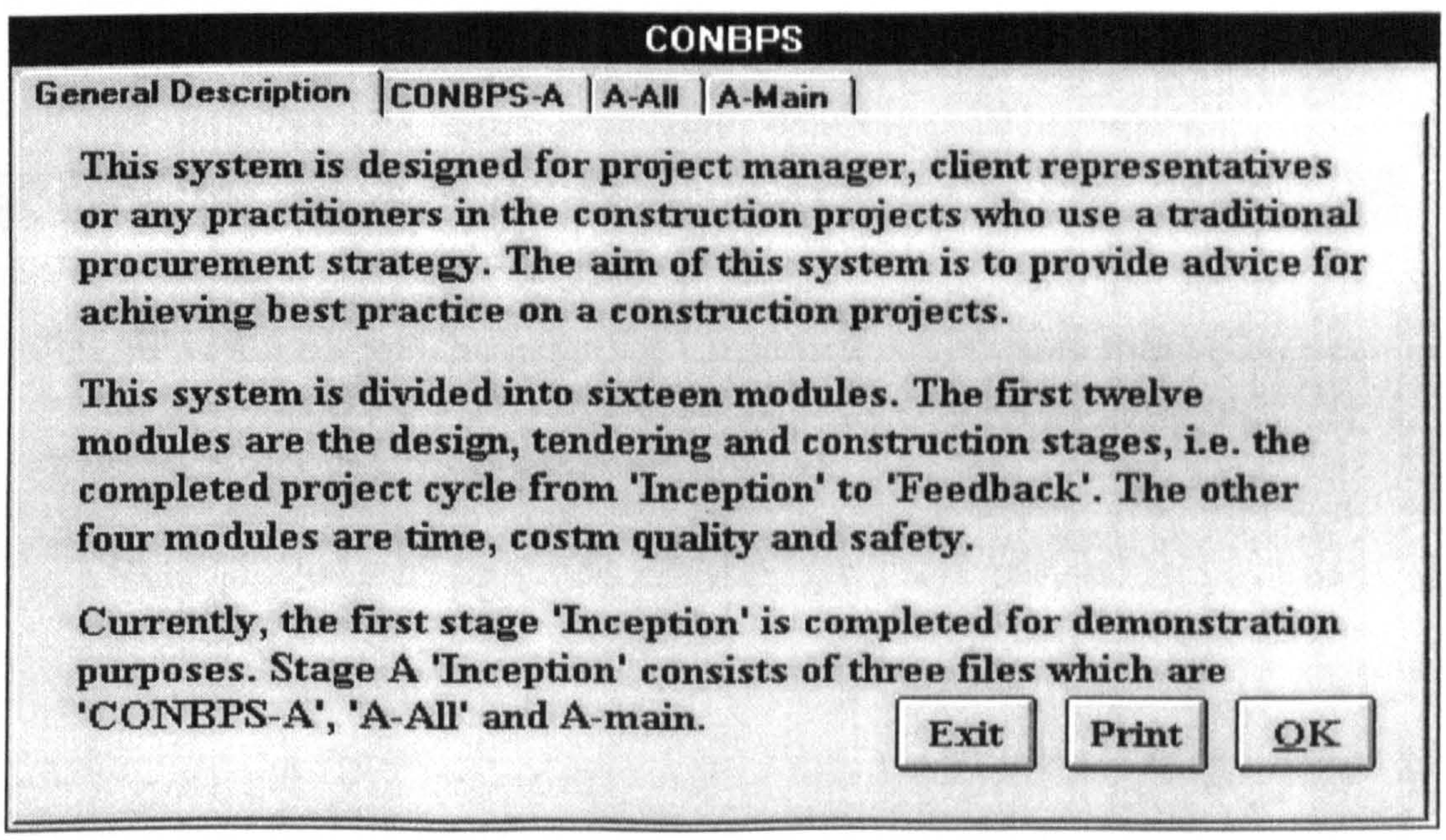


Figure 8.2 The icon 'About' of the system (General Description)

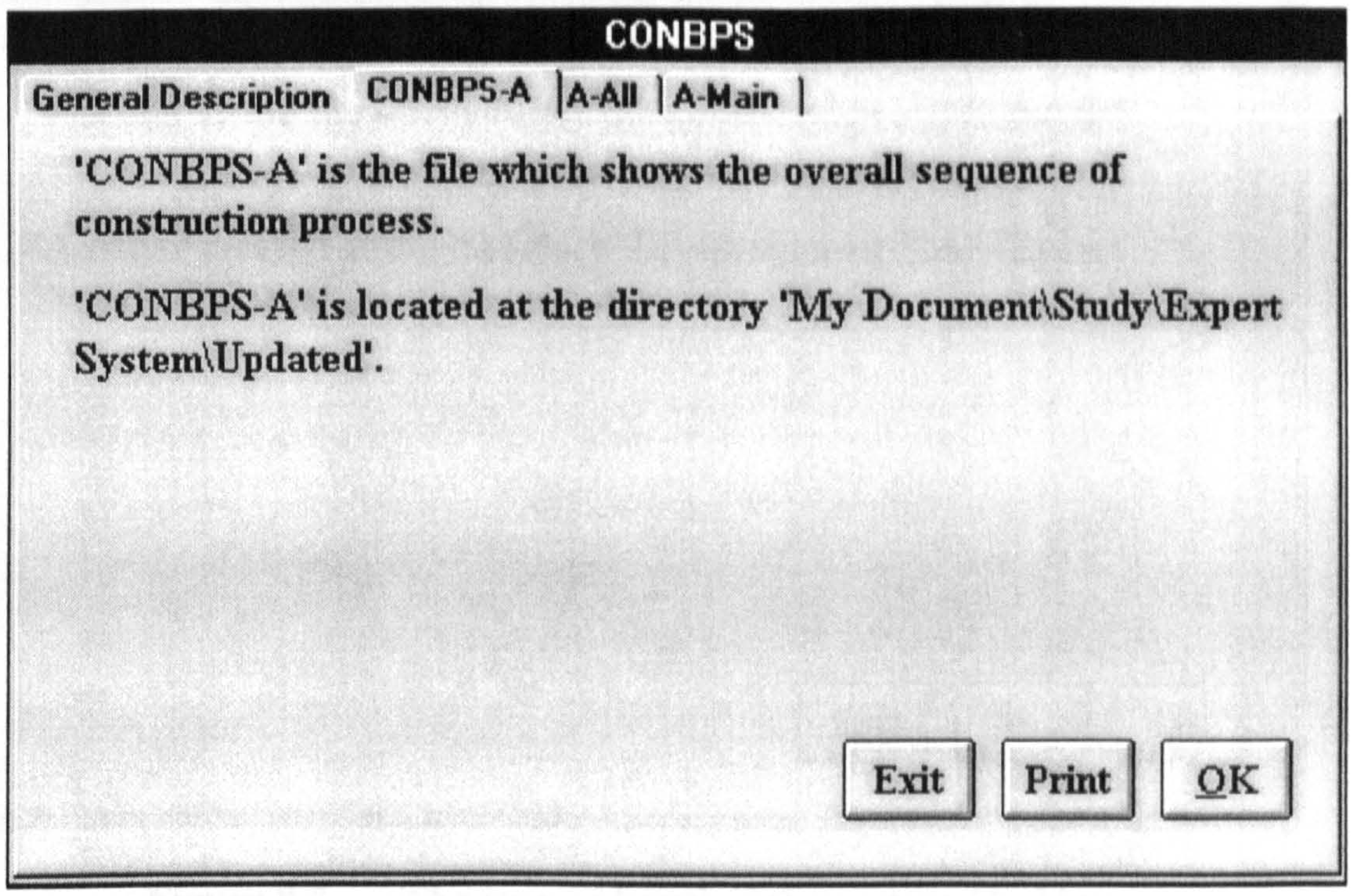


Figure 8.3 The icon 'About' of the system (CONBPS)

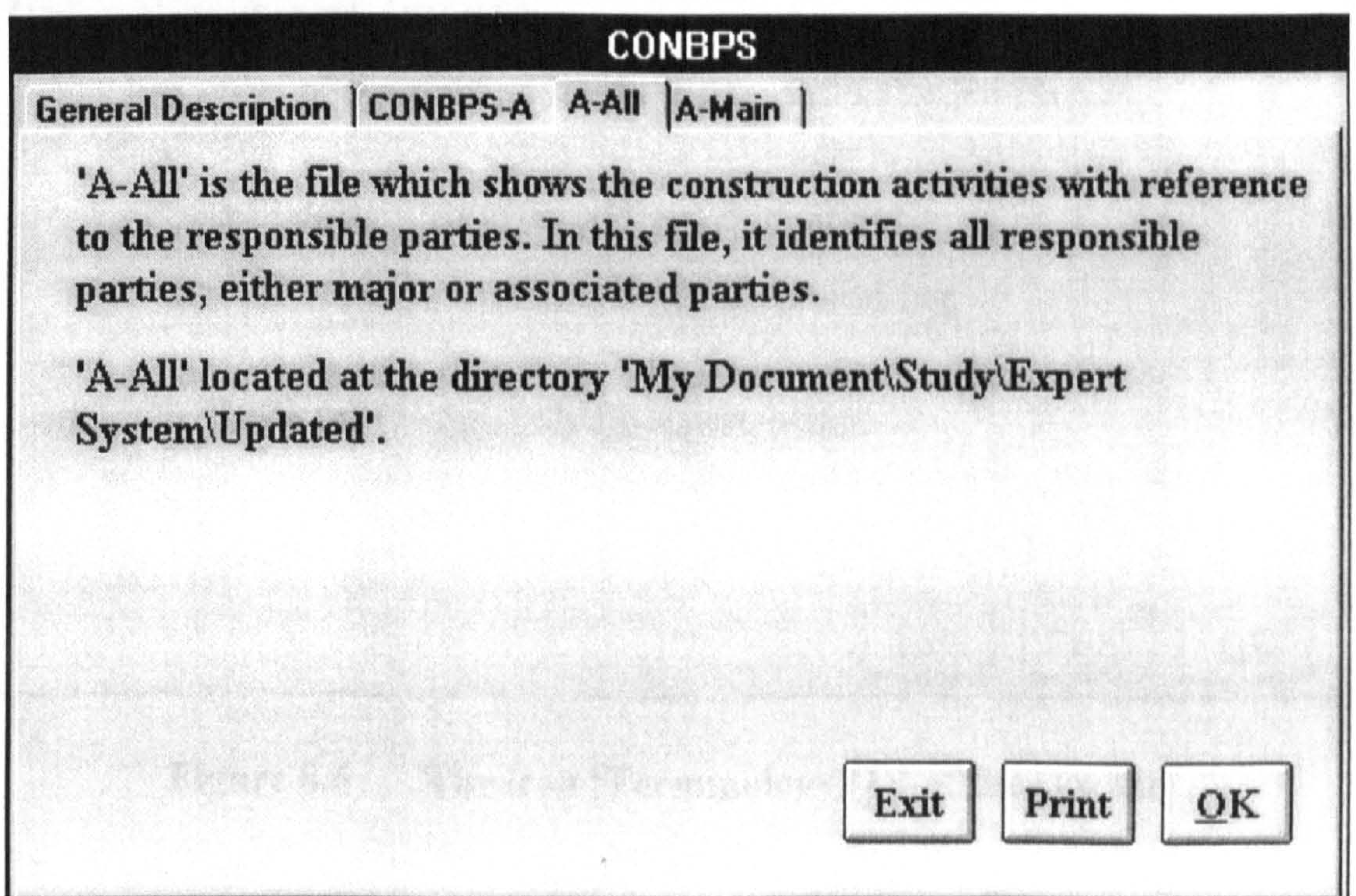


Figure 8.4 The icon 'About' of the system (A_All)

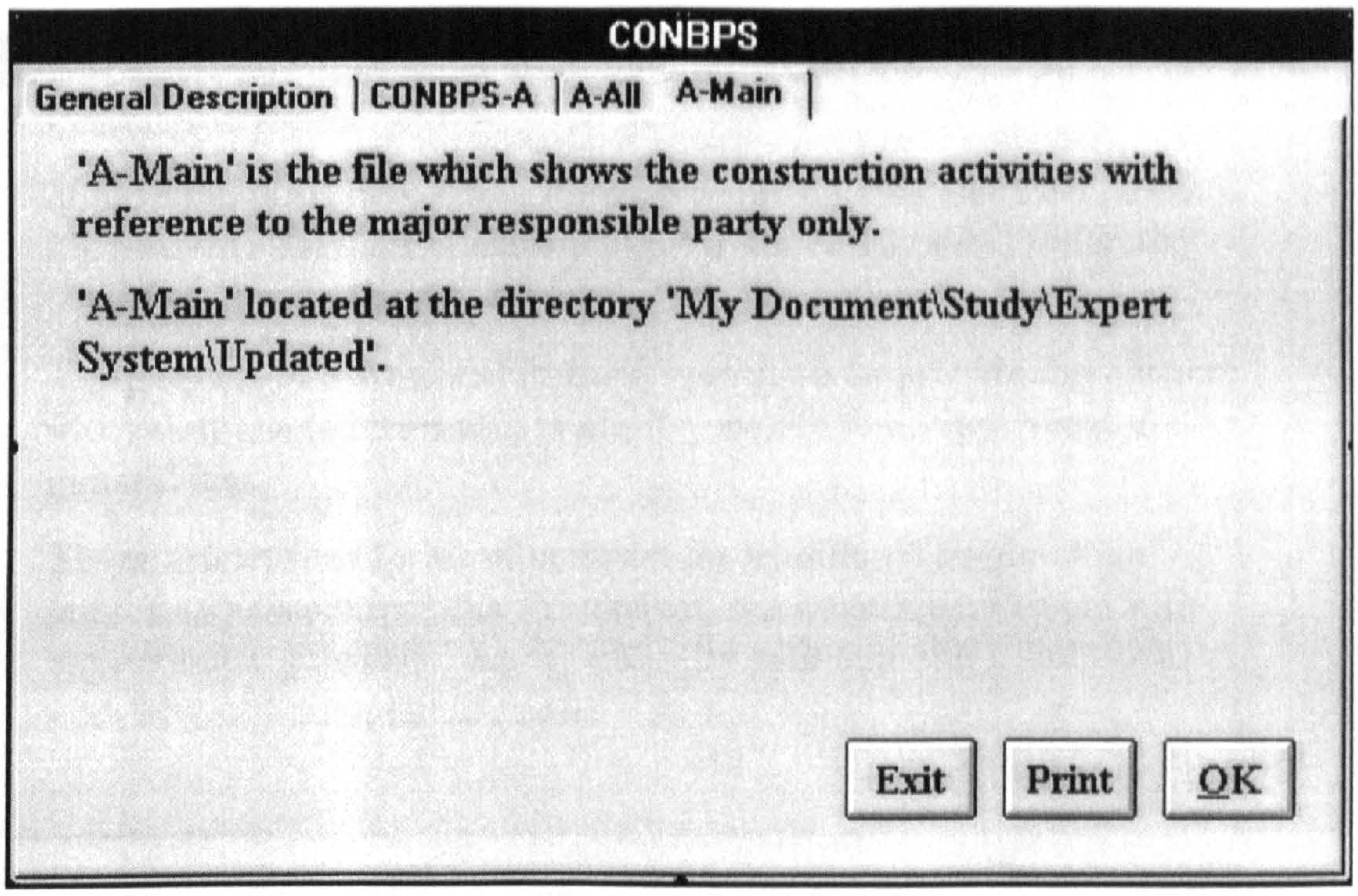


Figure 8.5 The icon 'About' of the system (A_Main)

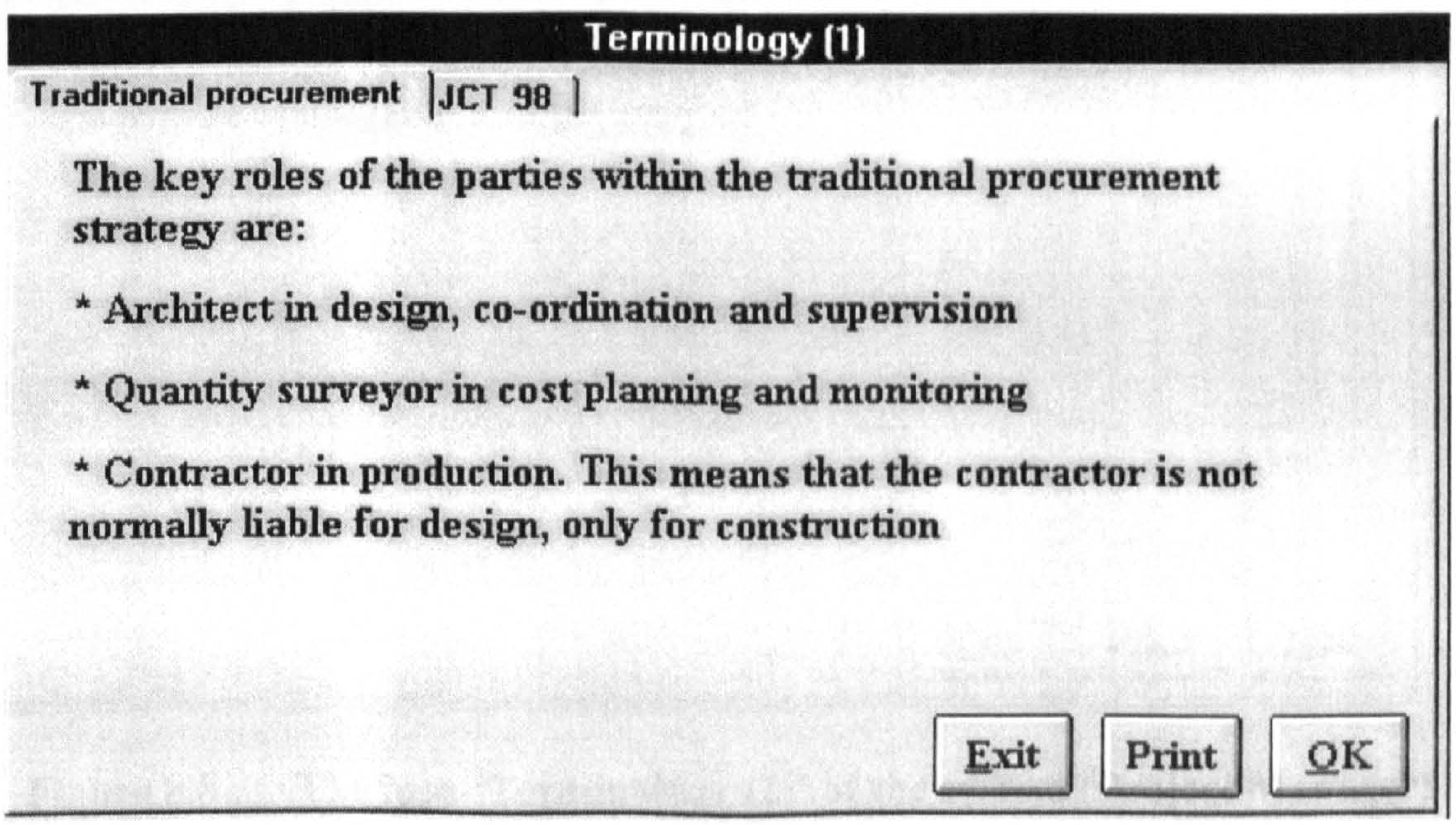


Figure 8.6 The icon 'Terminology (1)' of the system

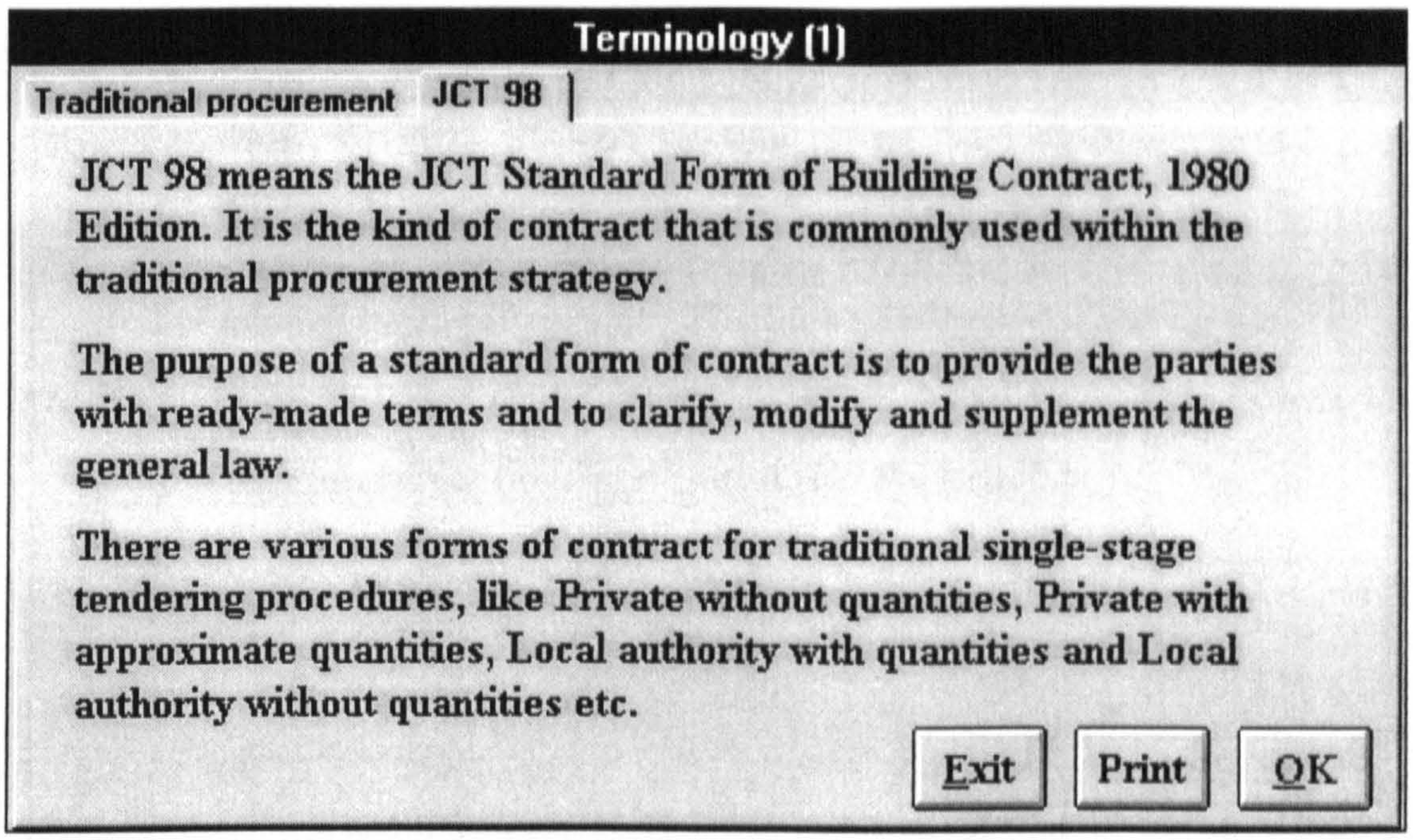


Figure 8.7 The icon 'Terminology (2)' of the system (JCT 98)

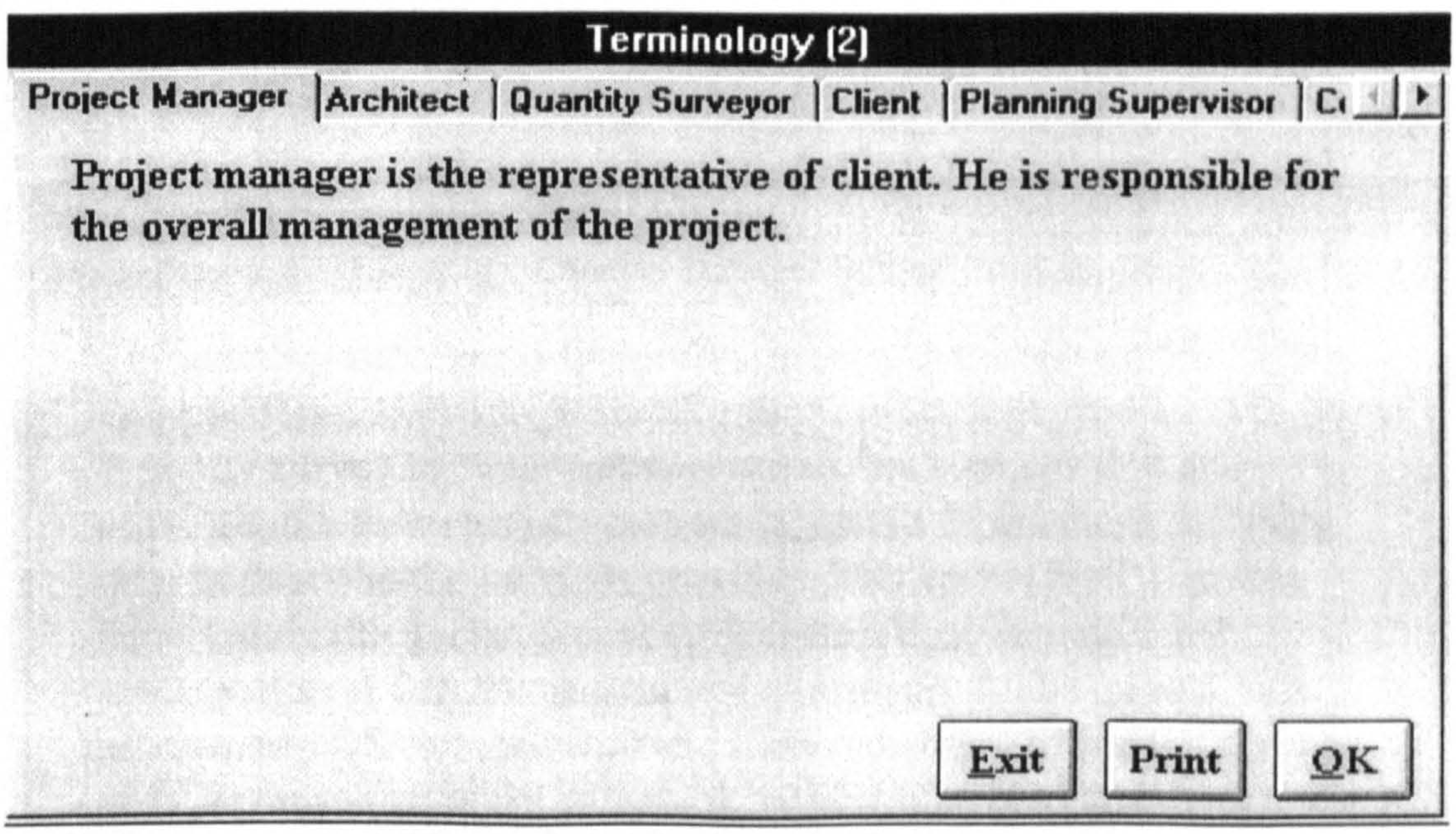


Figure 8.8 The icon 'Terminology (2)' of the system (Project Manager)

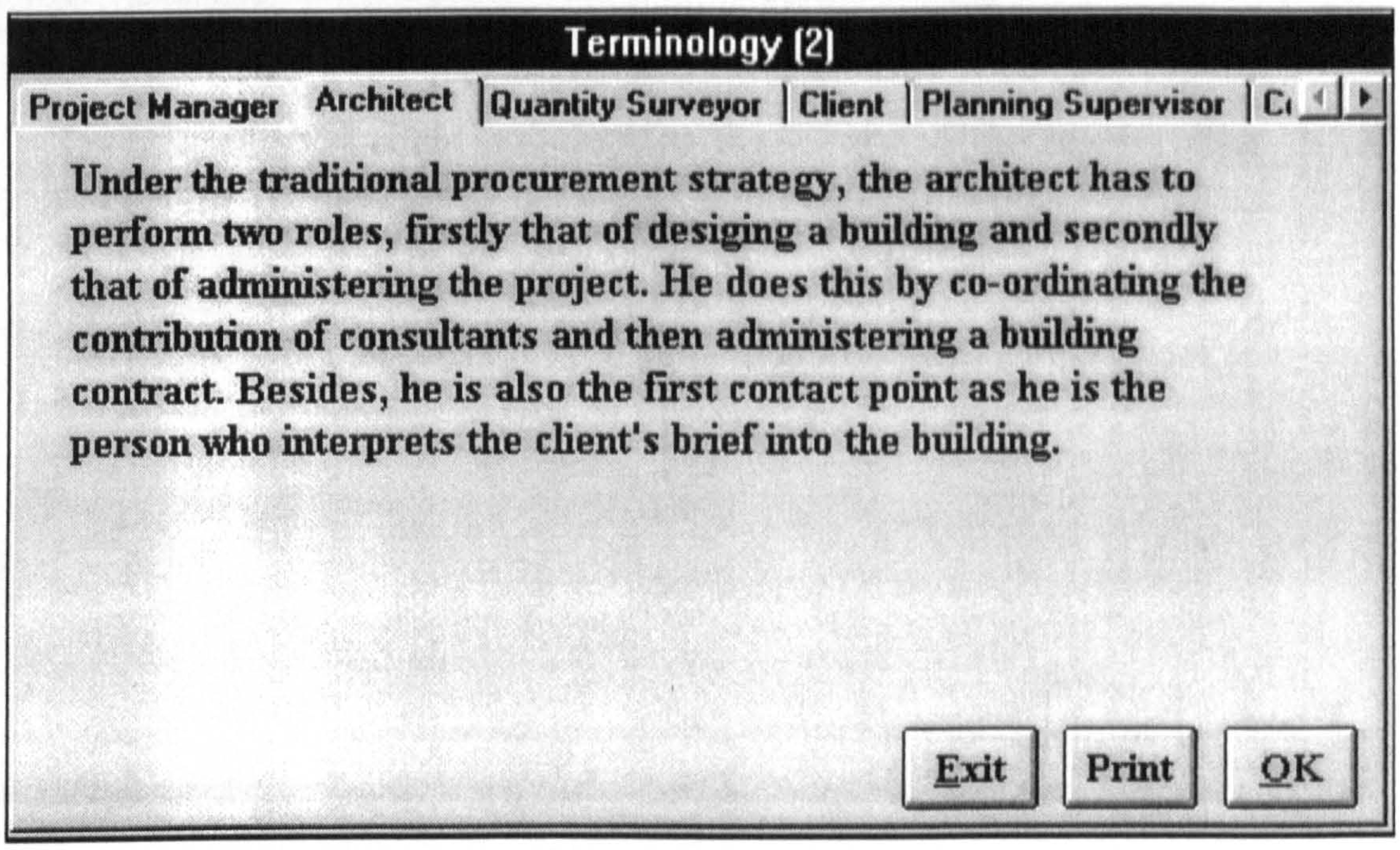


Figure 8.9 The icon 'Terminology (2)' of the system (Architect)

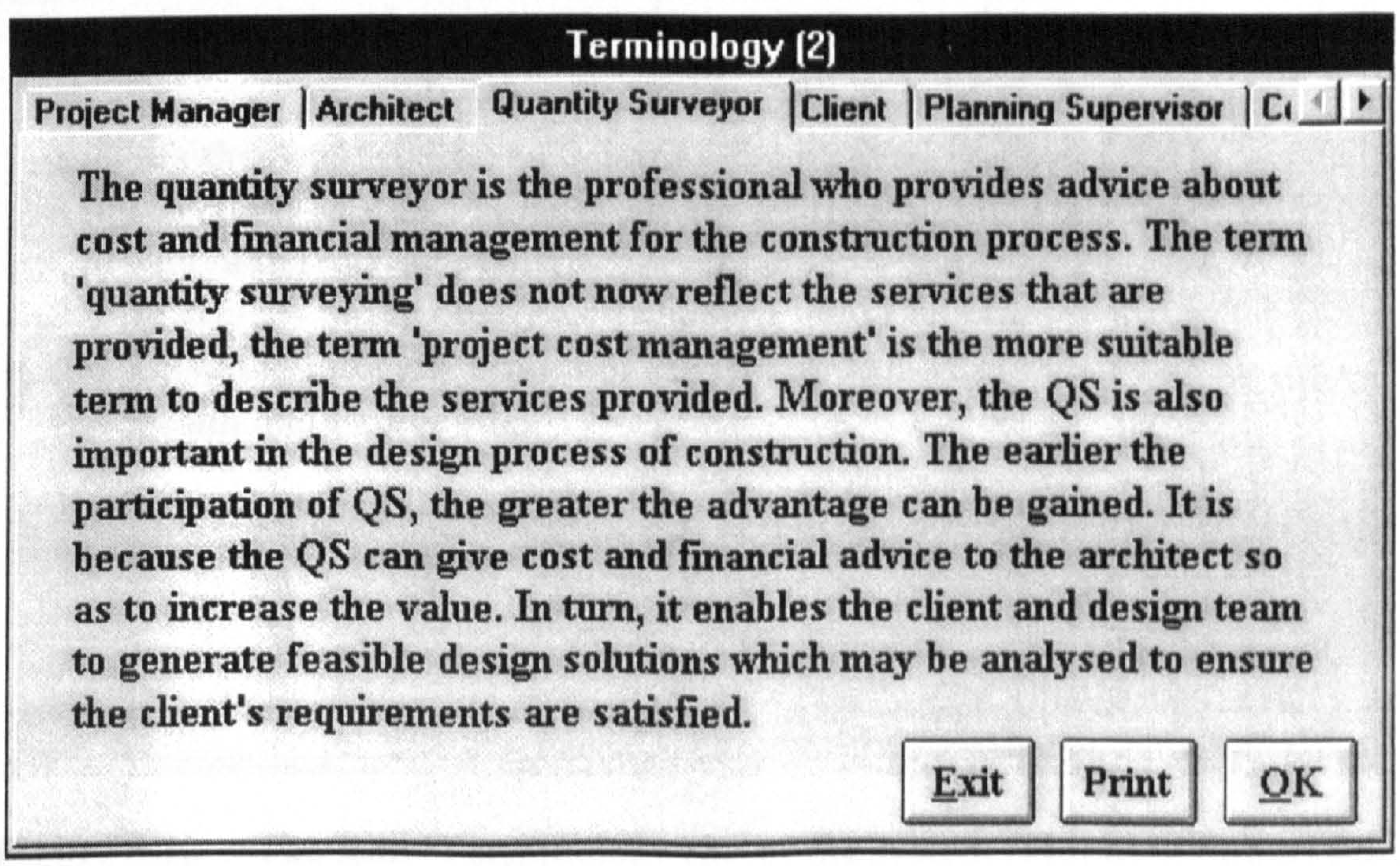


Figure 8.10 The icon 'Terminology (2)' of the system (Quantity Surveyor)

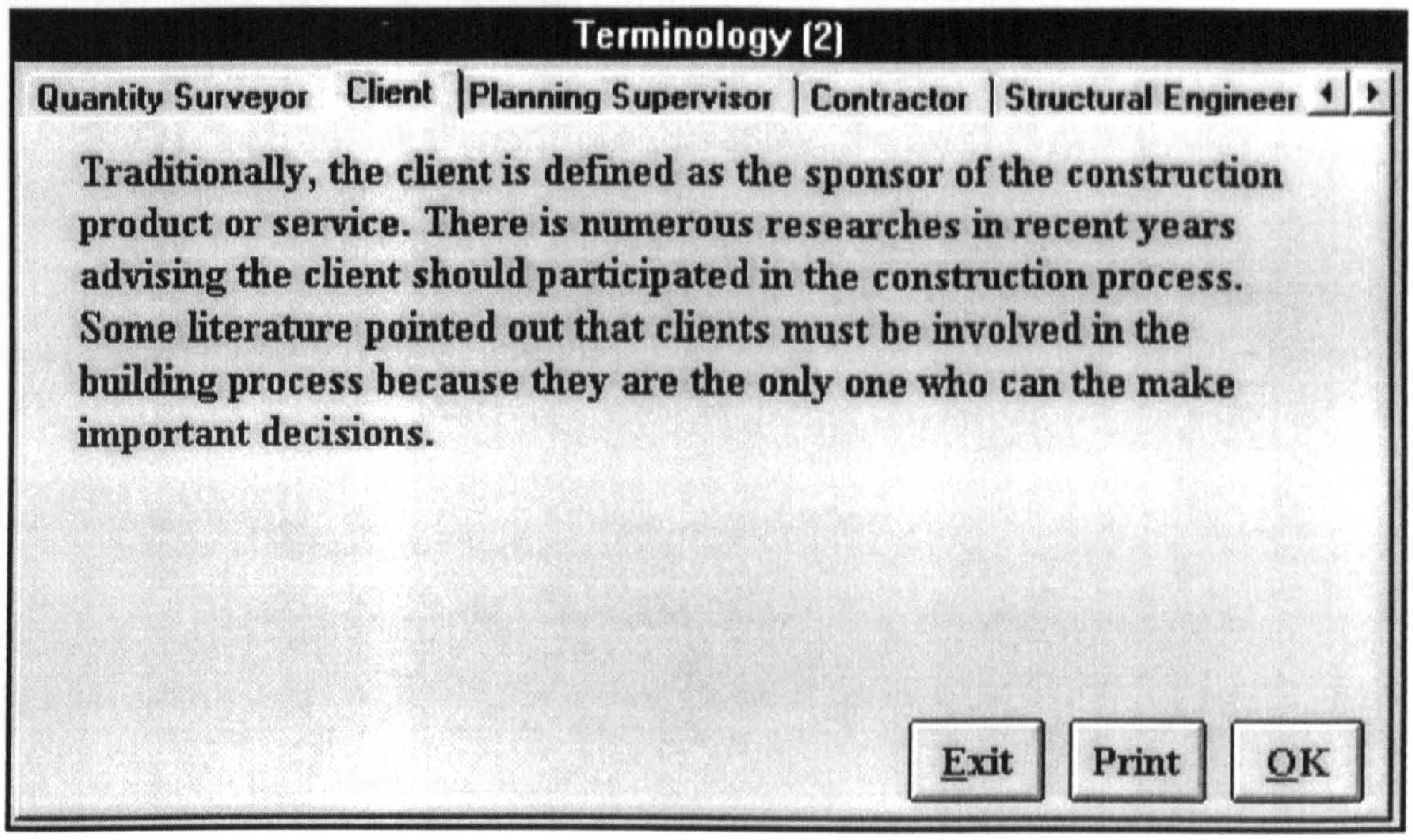


Figure 8.11 The icon 'Terminology (2)' of the system (Client)

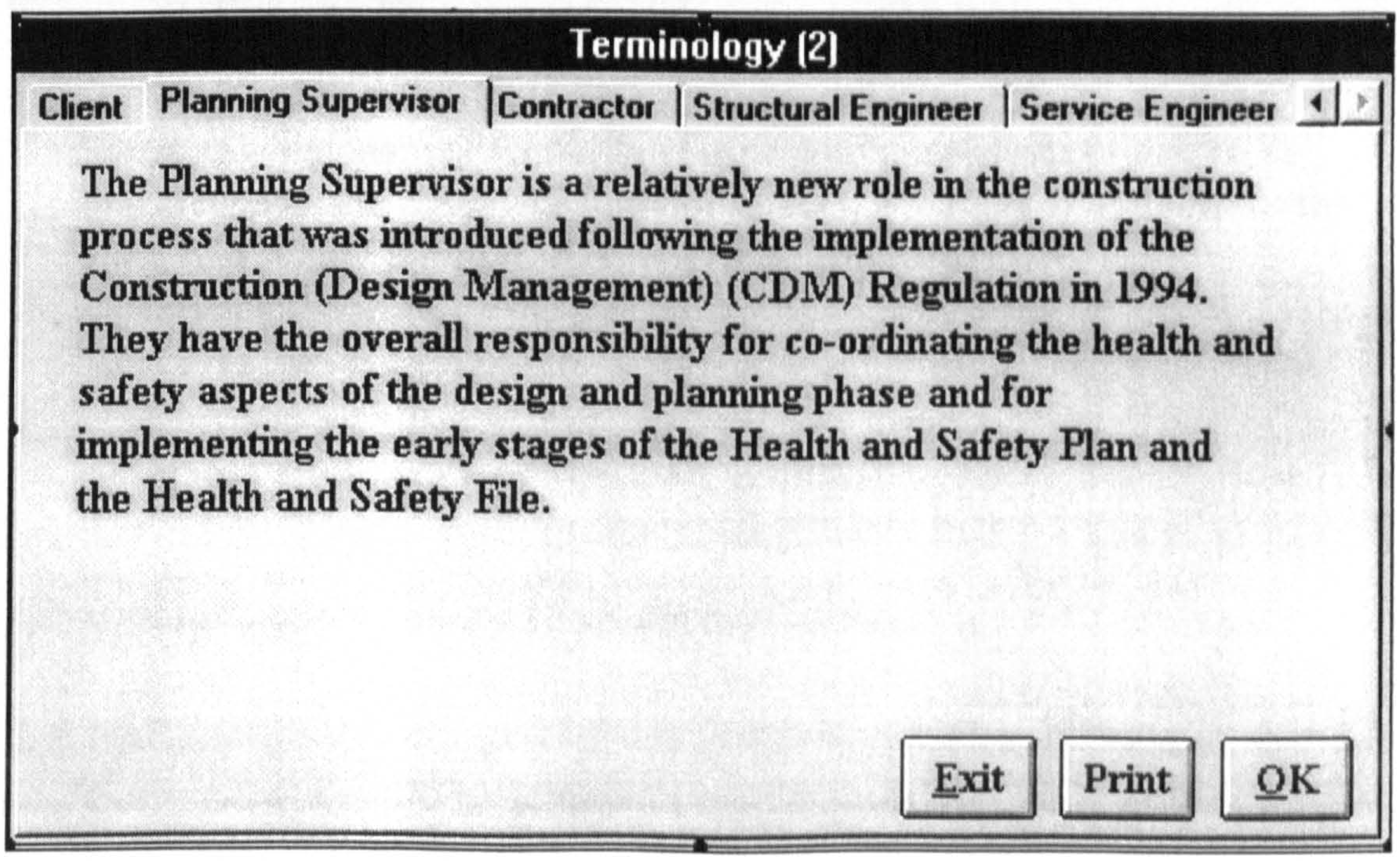


Figure 8.12 The icon 'Terminology (2)' of the system (Planning Supervisor)

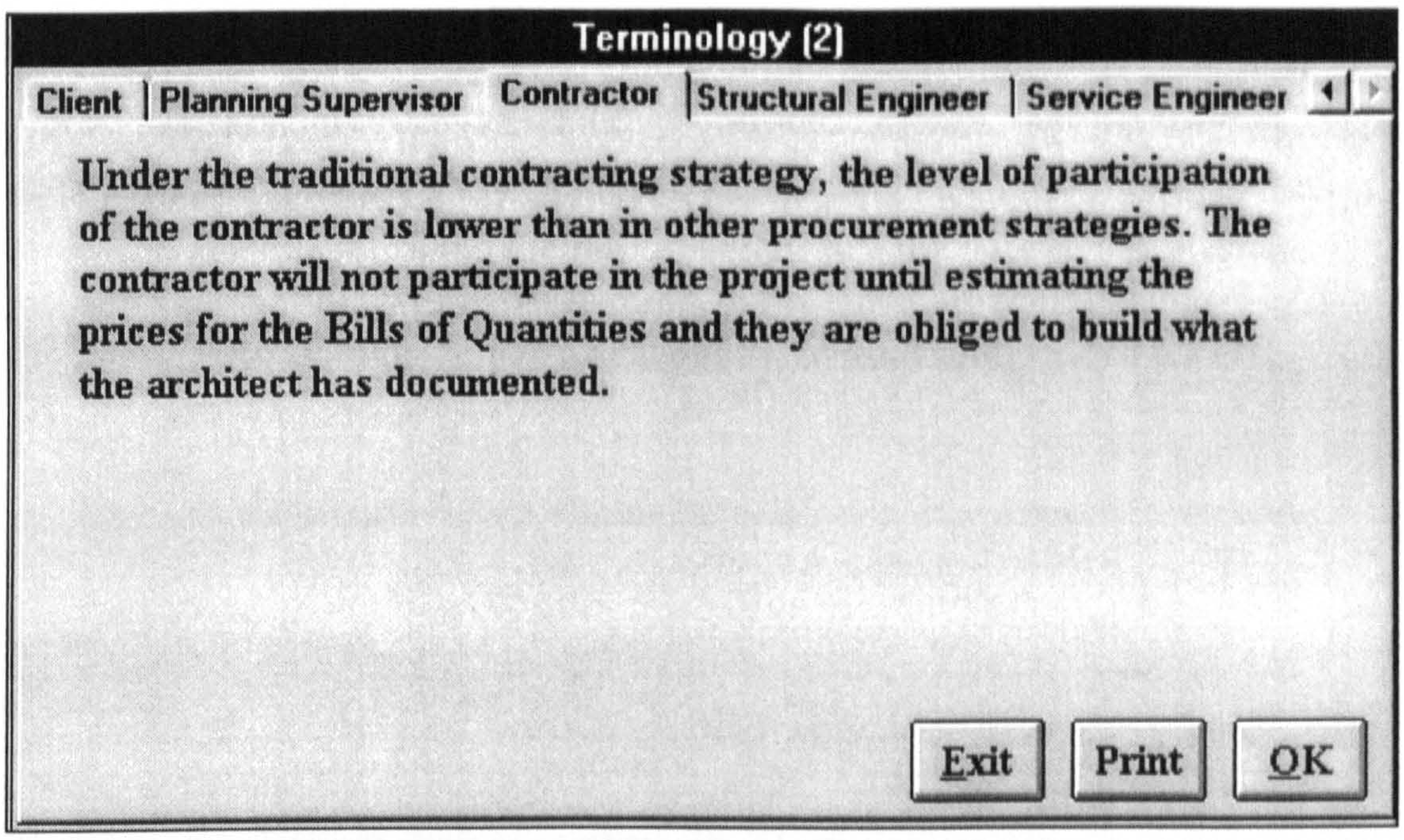


Figure 8.13 The icon 'Terminology (2)' of the system (Contractor)

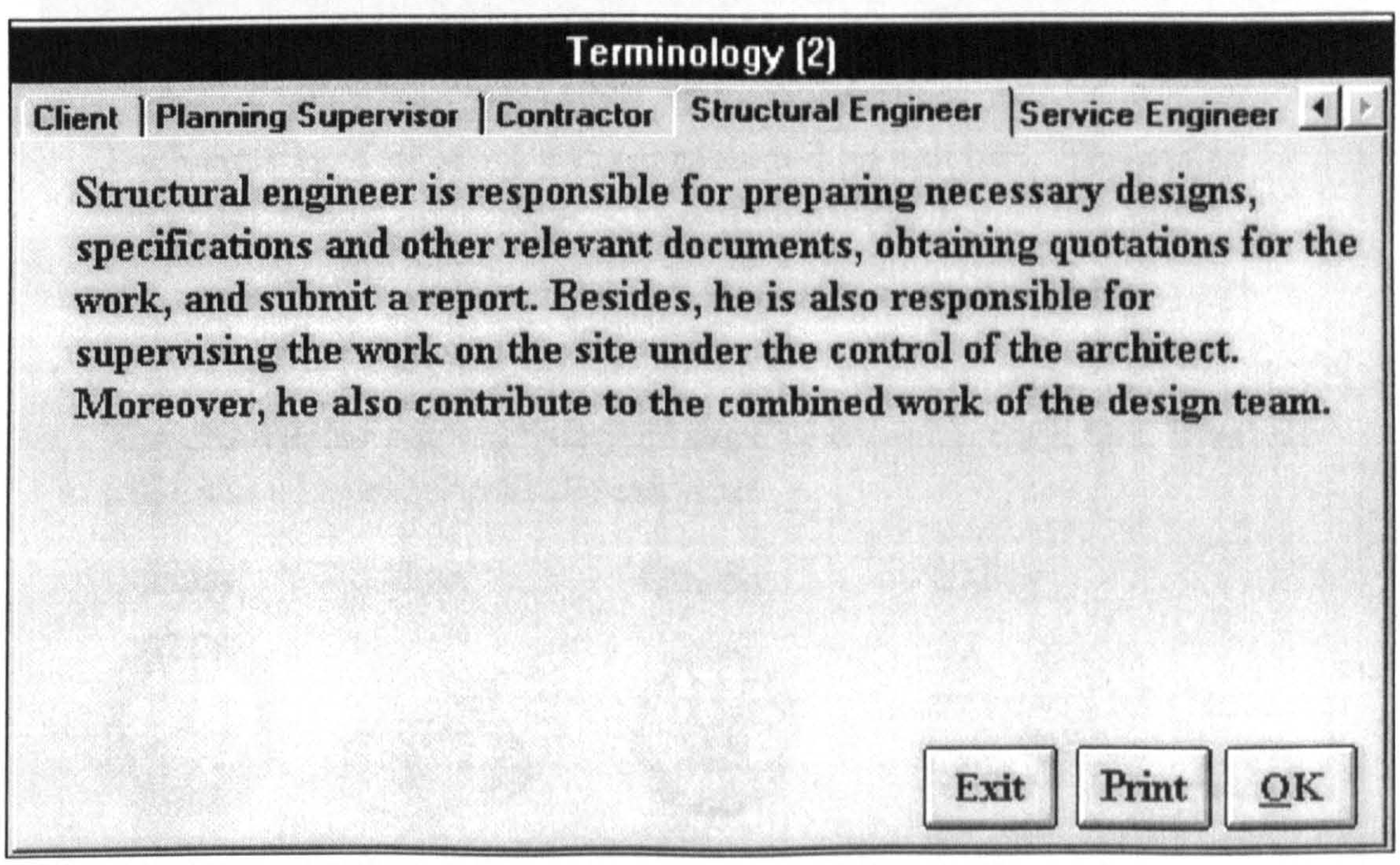


Figure 8.14 The icon 'Terminology (2)' of the system (Structural Engineer)

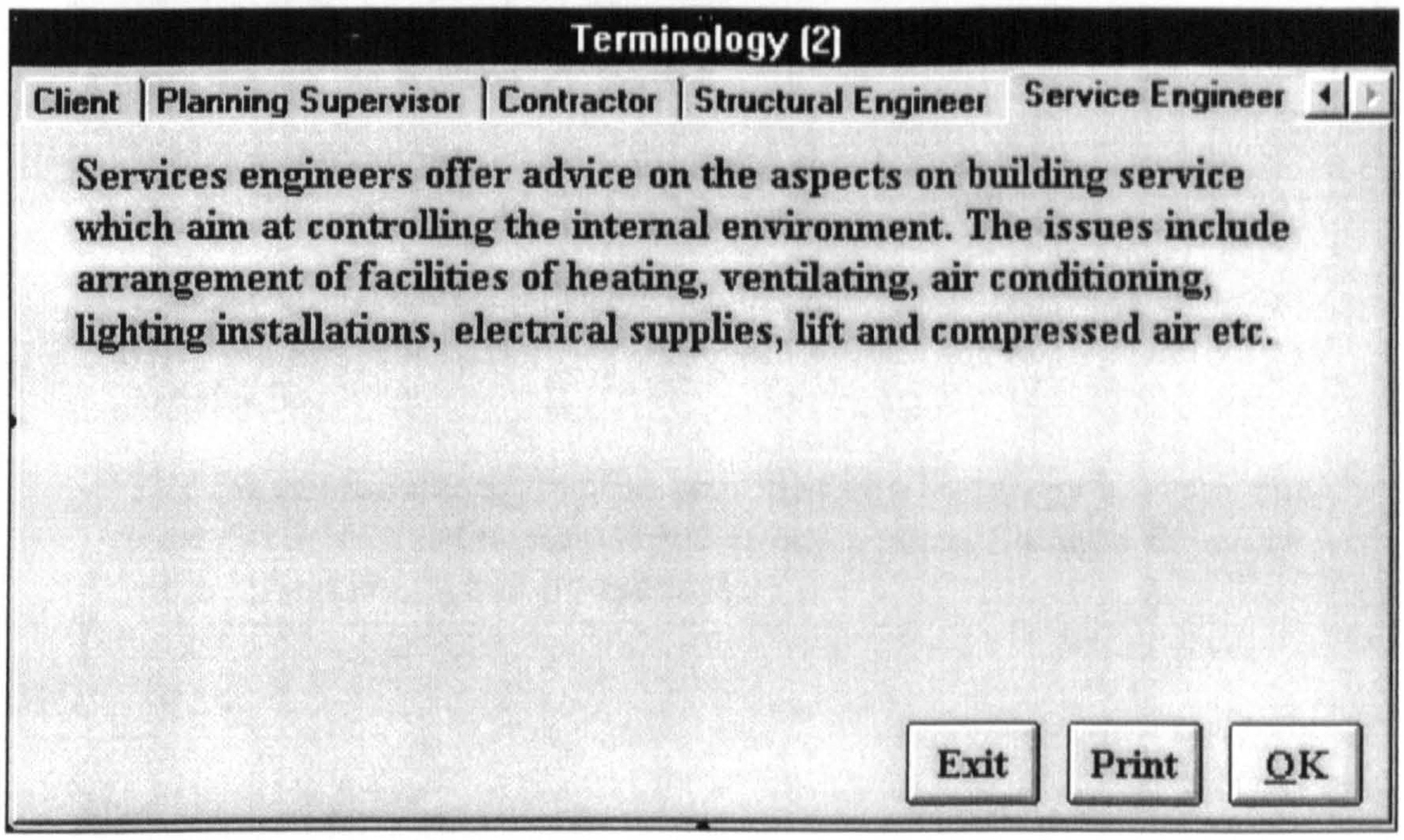


Figure 8.15 The icon 'Terminology (2)' of the system (Service Engineer)

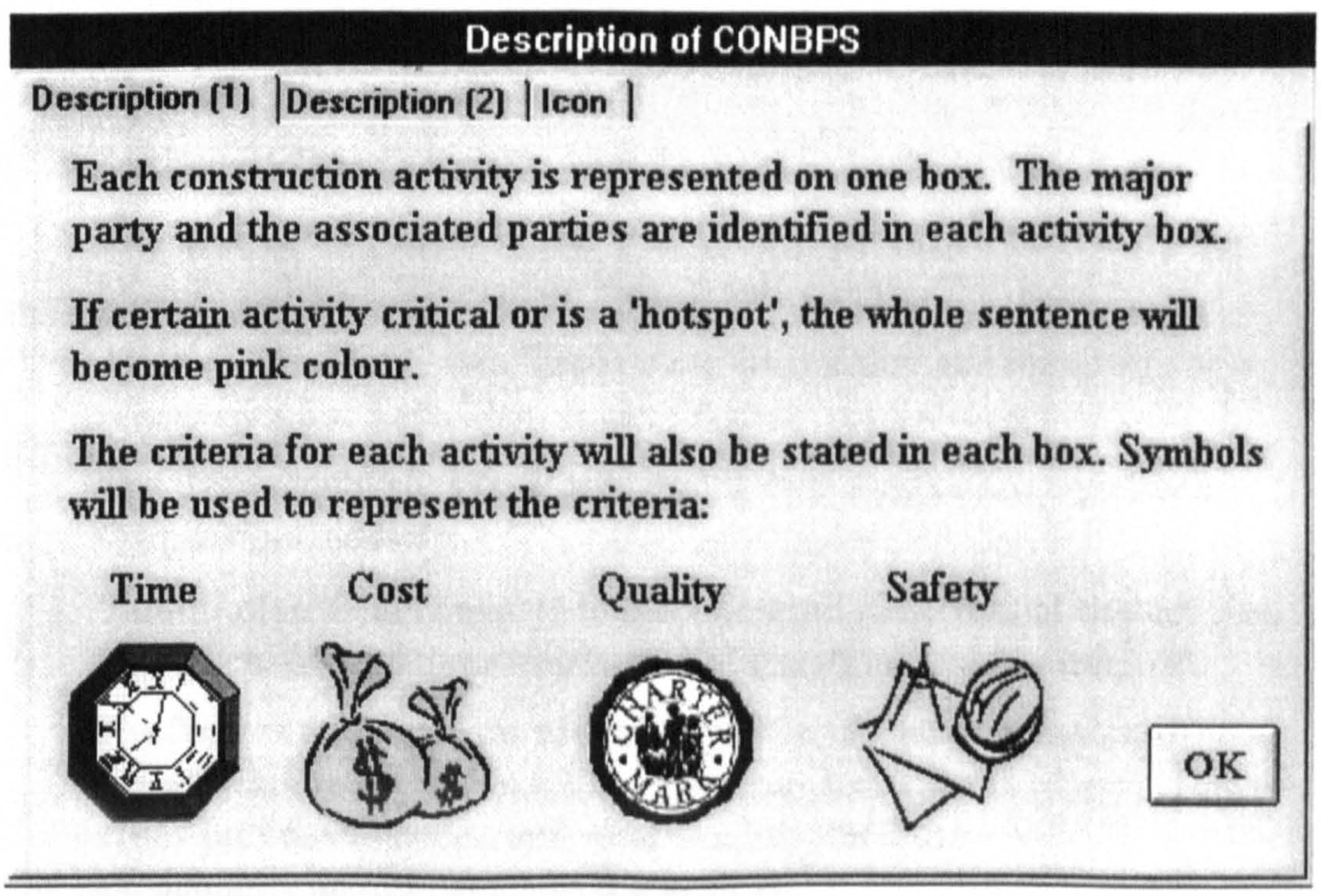


Figure 8.16 The icon 'Description (1)' of the system

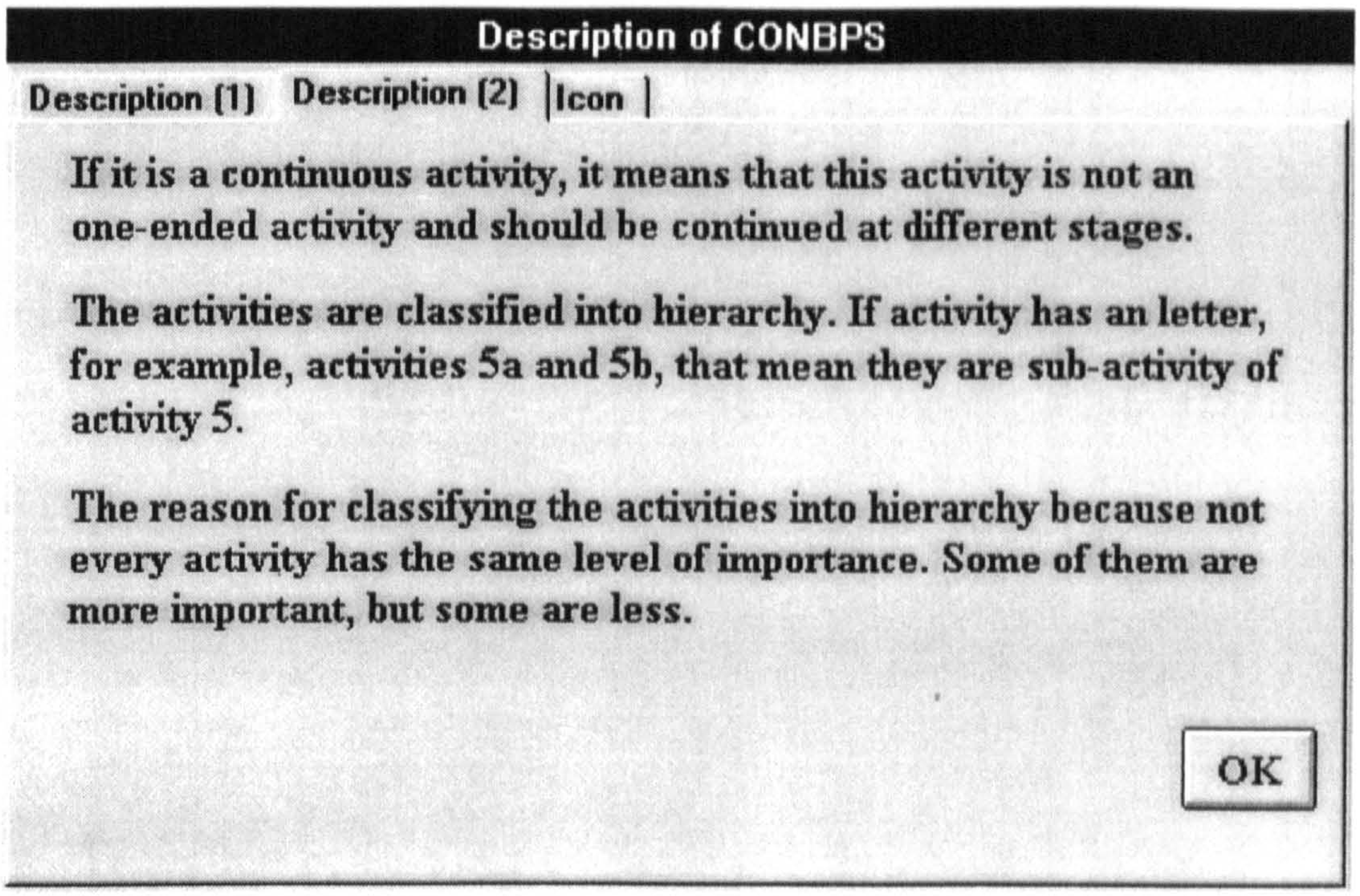


Figure 8.17 The icon 'Description (2)' of the system

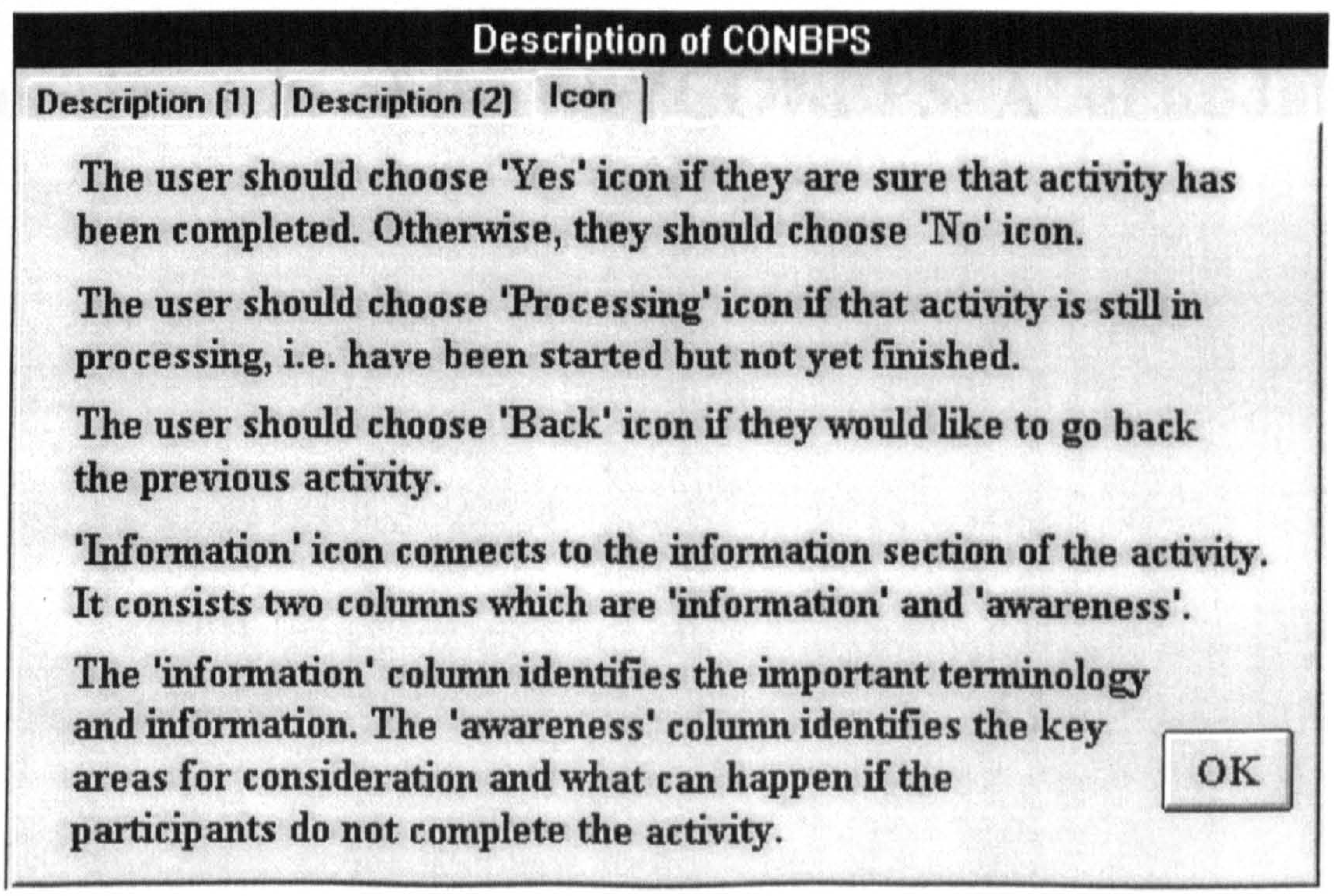


Figure 8.18 The icon 'Icon' of the system

Appendix 9

Decision tree of the file 'CONBPS_A' of updated CONBPS

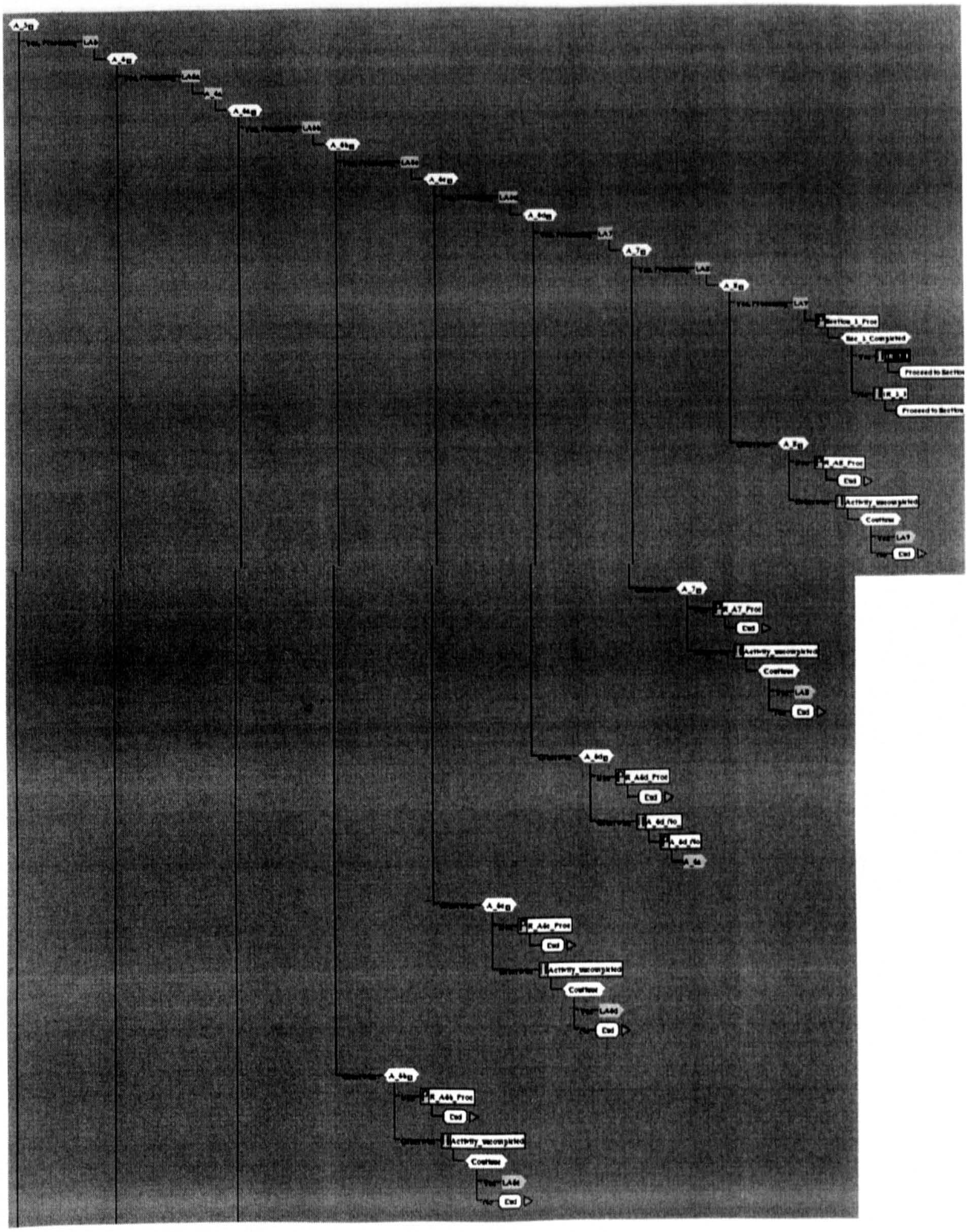


Figure 9.1 Decision tree of 'CONBPS_A' – Section 2 (Part 1)

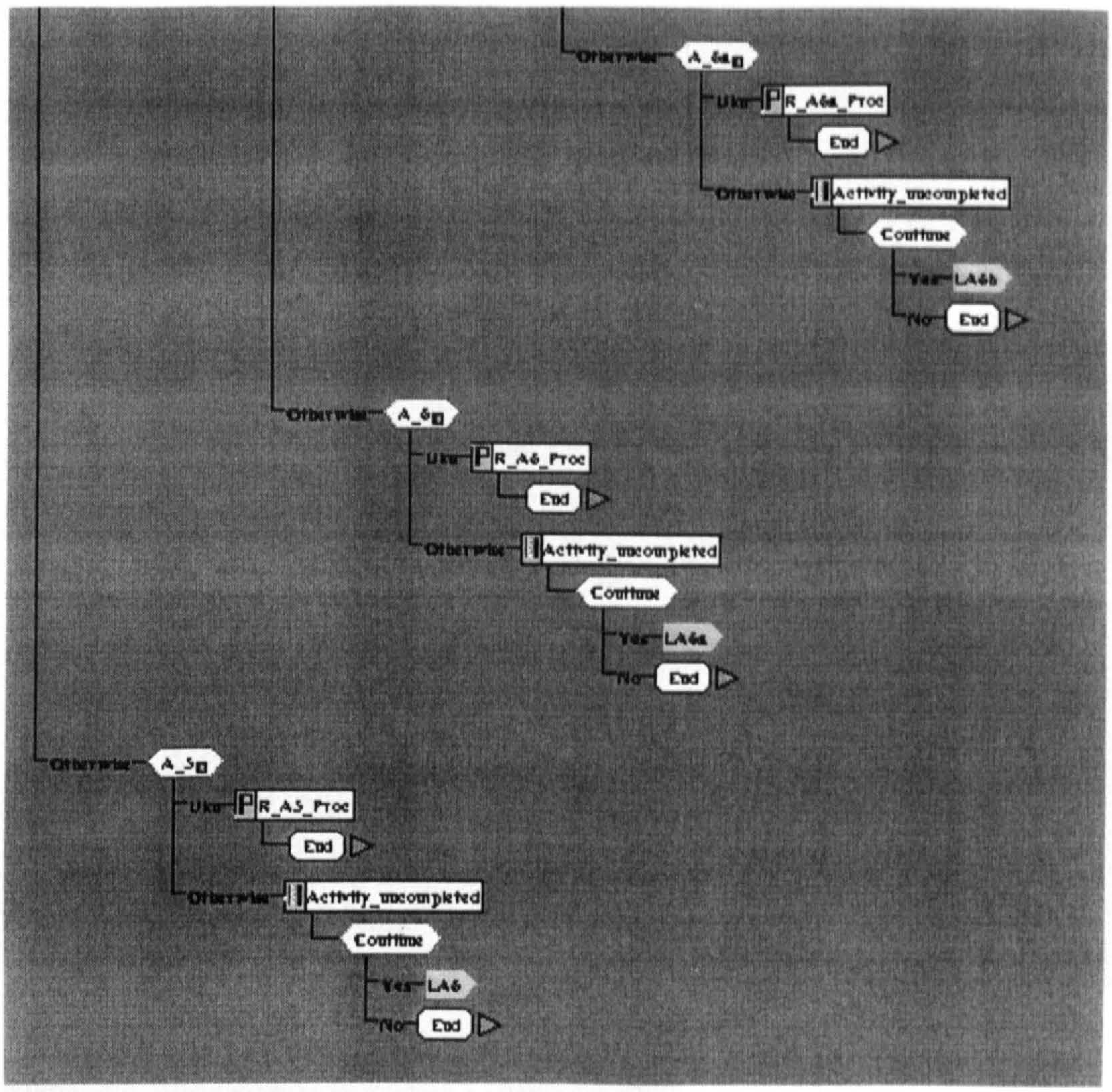


Figure 9.1 Decision tree of 'CONBPS_A' – Section 2 (Part 2)

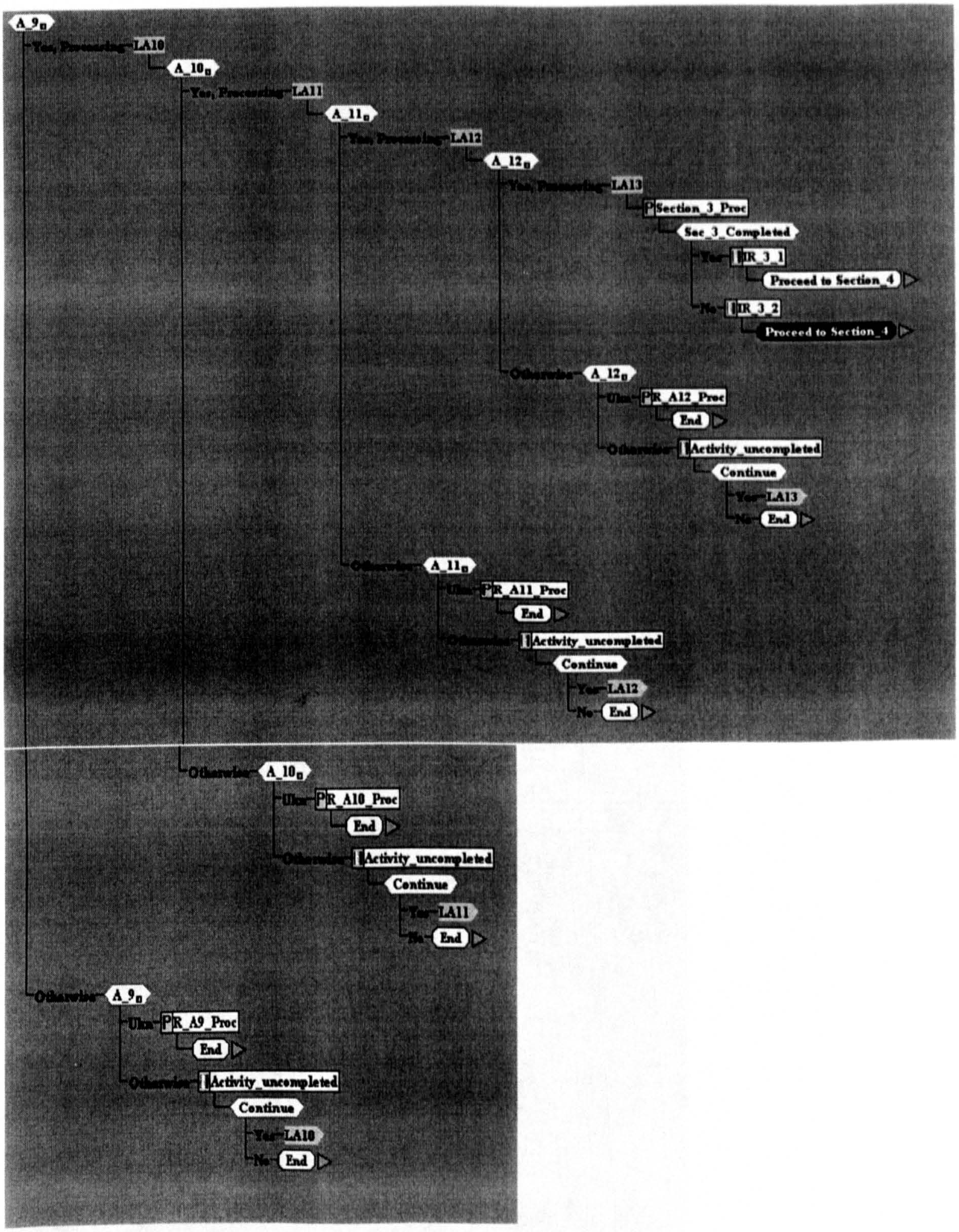


Figure 9.2 Decision tree of 'CONBPS_A' – Section 3

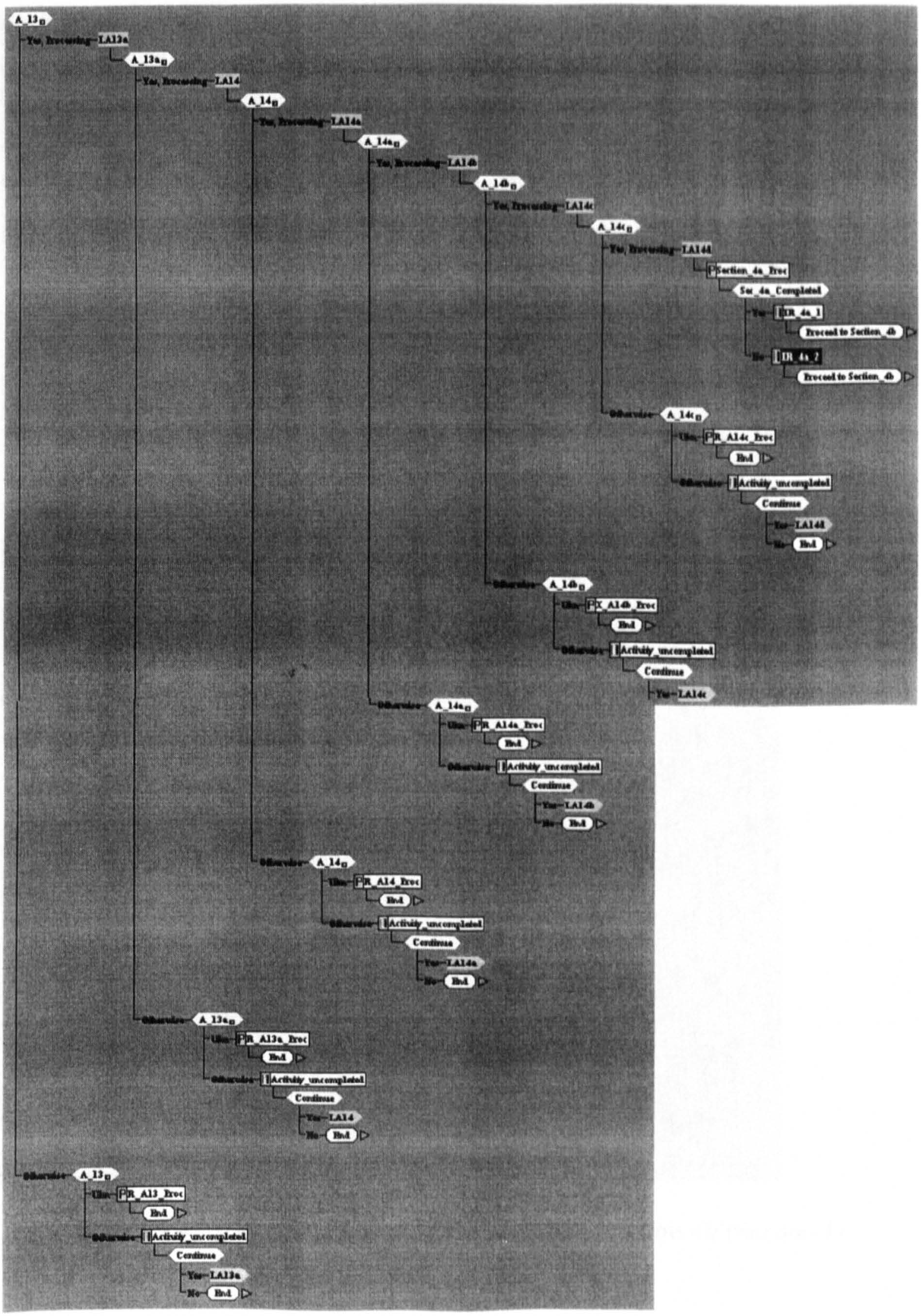


Figure 9.3 Decision tree of 'CONBPS_A' – Section 4a

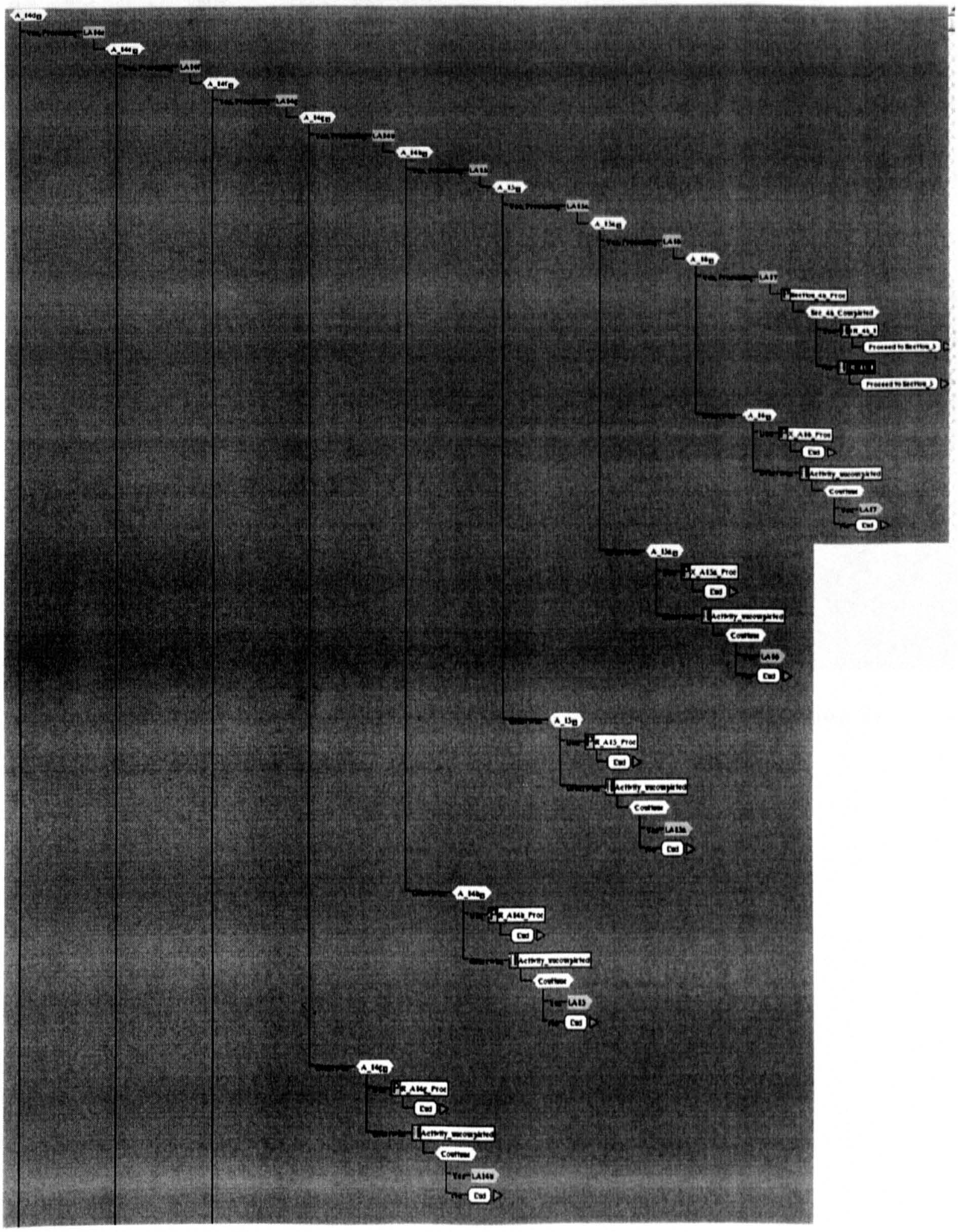


Figure 9.4 Decision tree of 'CONBPS_A' – Section 4b (Section 1)

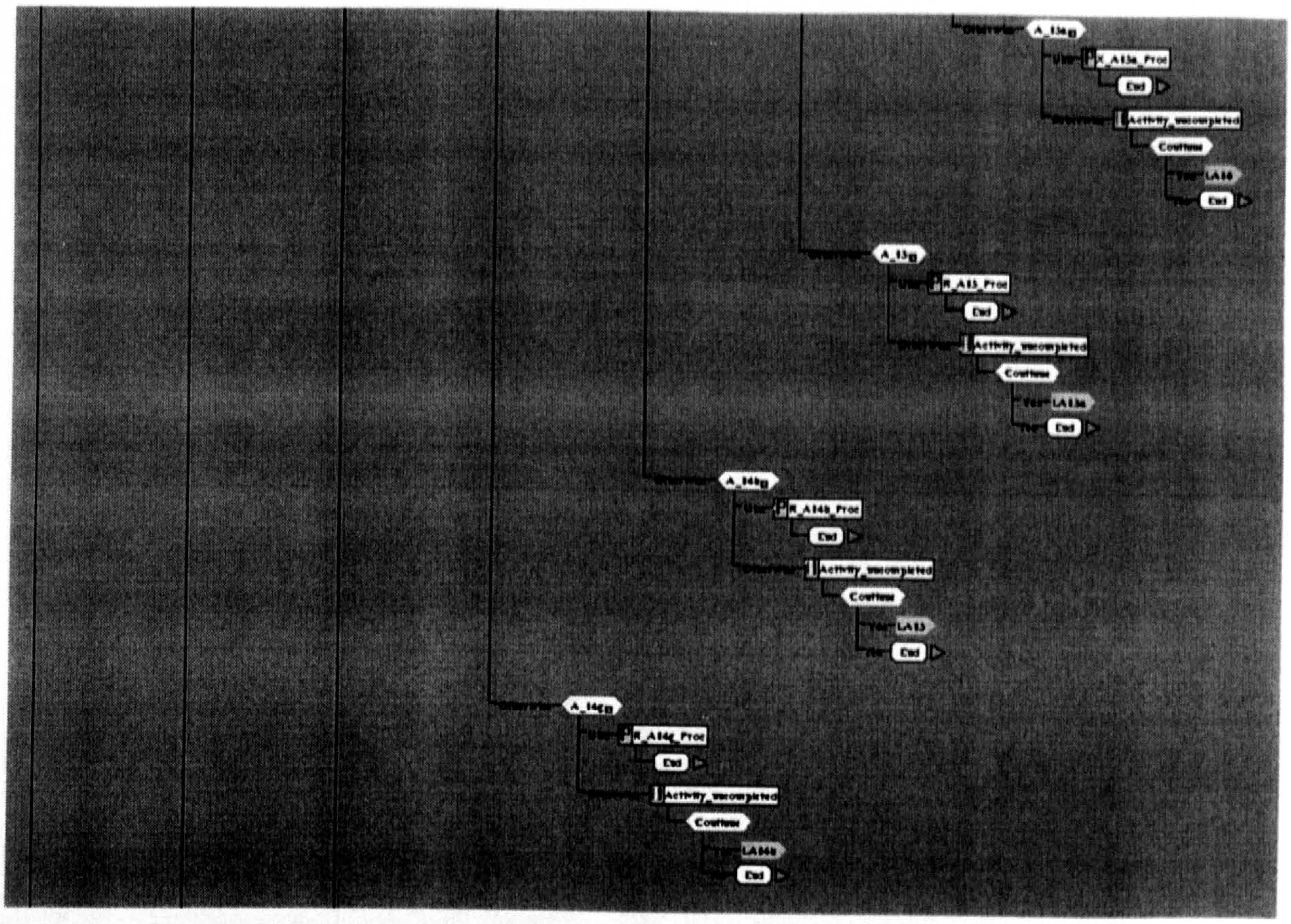


Figure 9.4 Decision tree of 'CONBPS_A' – Section 4b (Section 2)

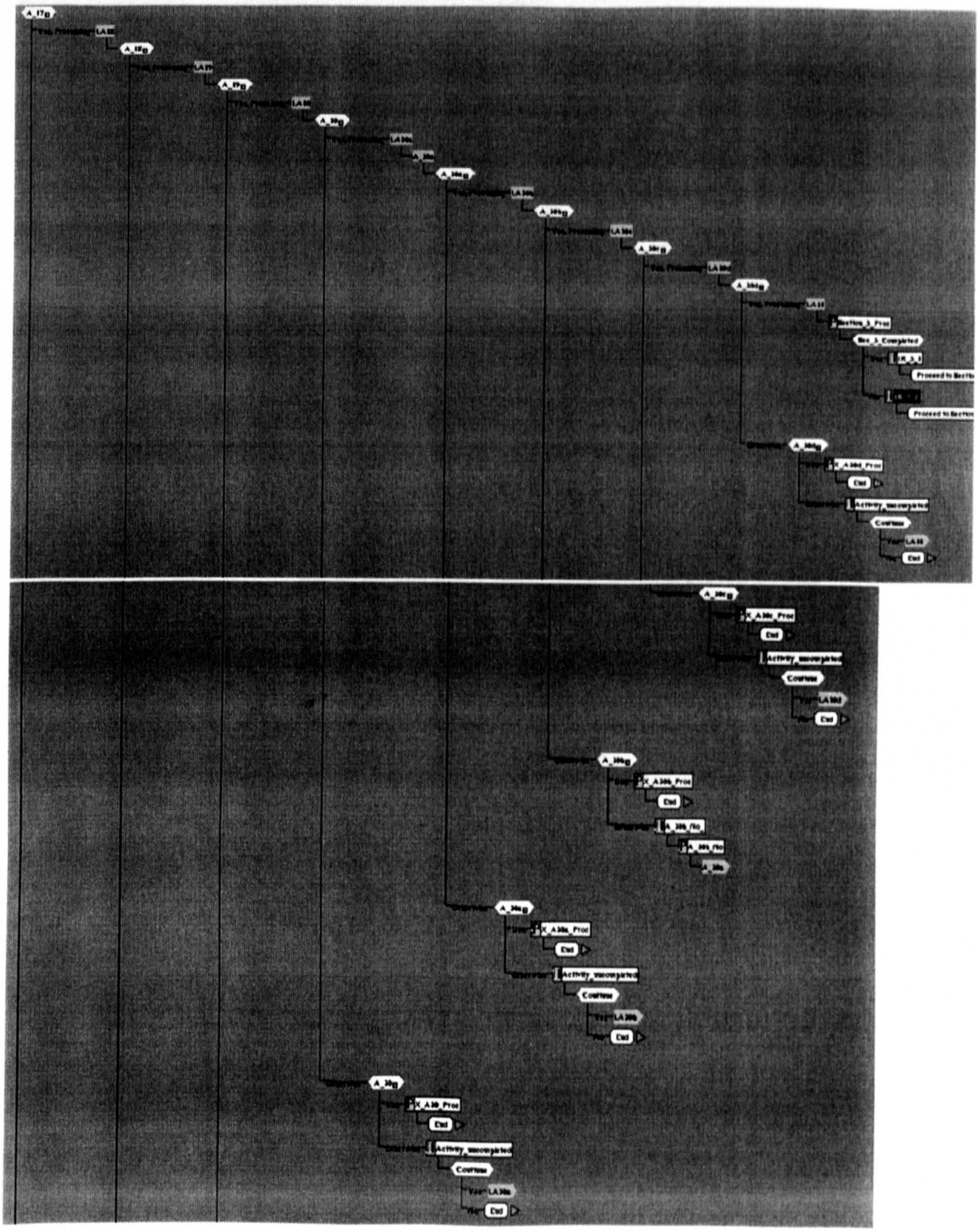


Figure 9.5 Decision tree of 'CONBPS_A' – Section 5 (Part 1)

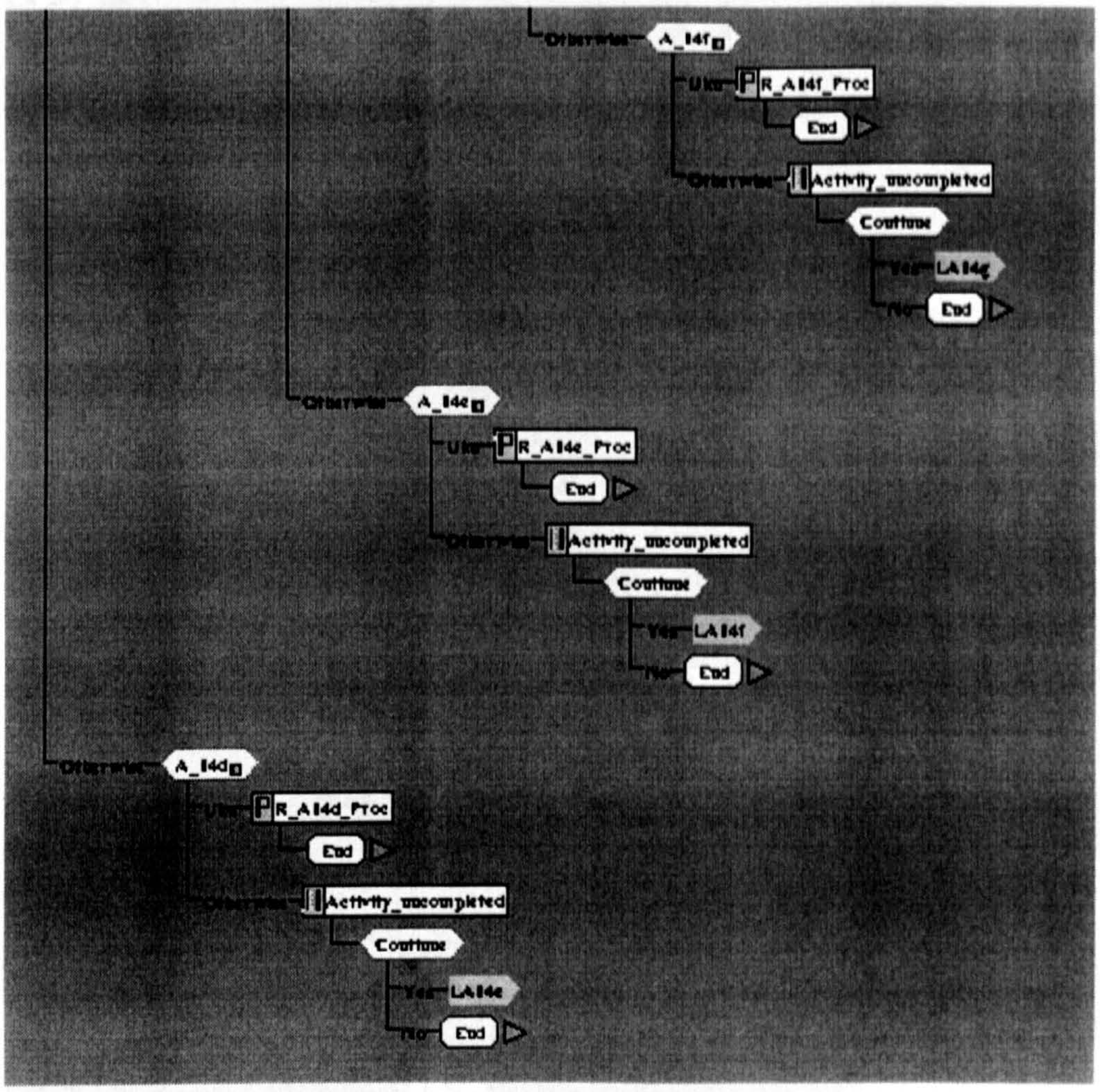


Figure 9.5 Decision tree of 'CONBPS_A' – Section 5 (Part 2)

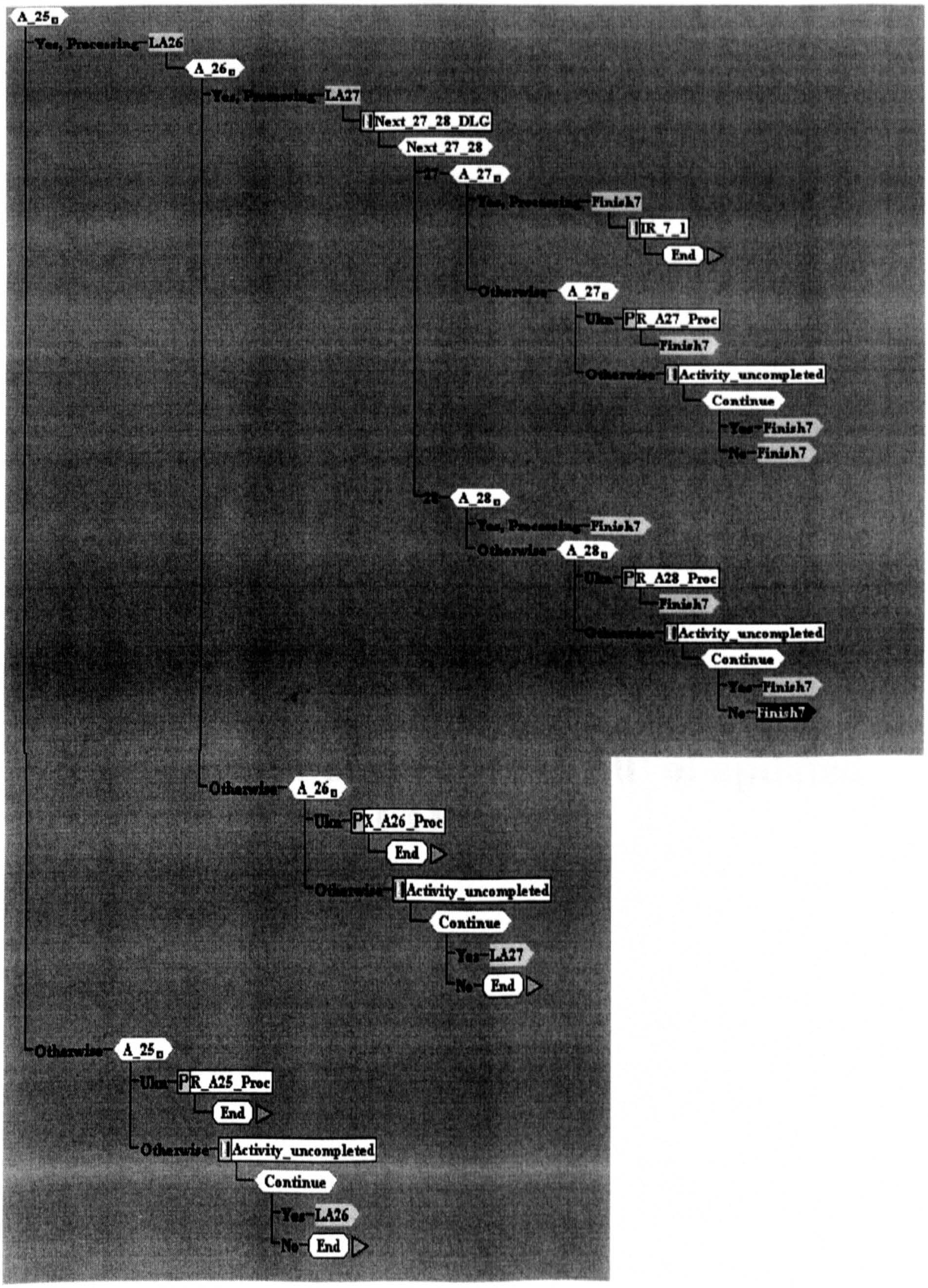


Figure 9.6 Decision tree of 'CONBPS_A' – Section 7

Appendix 10

Decision tree of the file ‘A_All’ of updated CONBPS

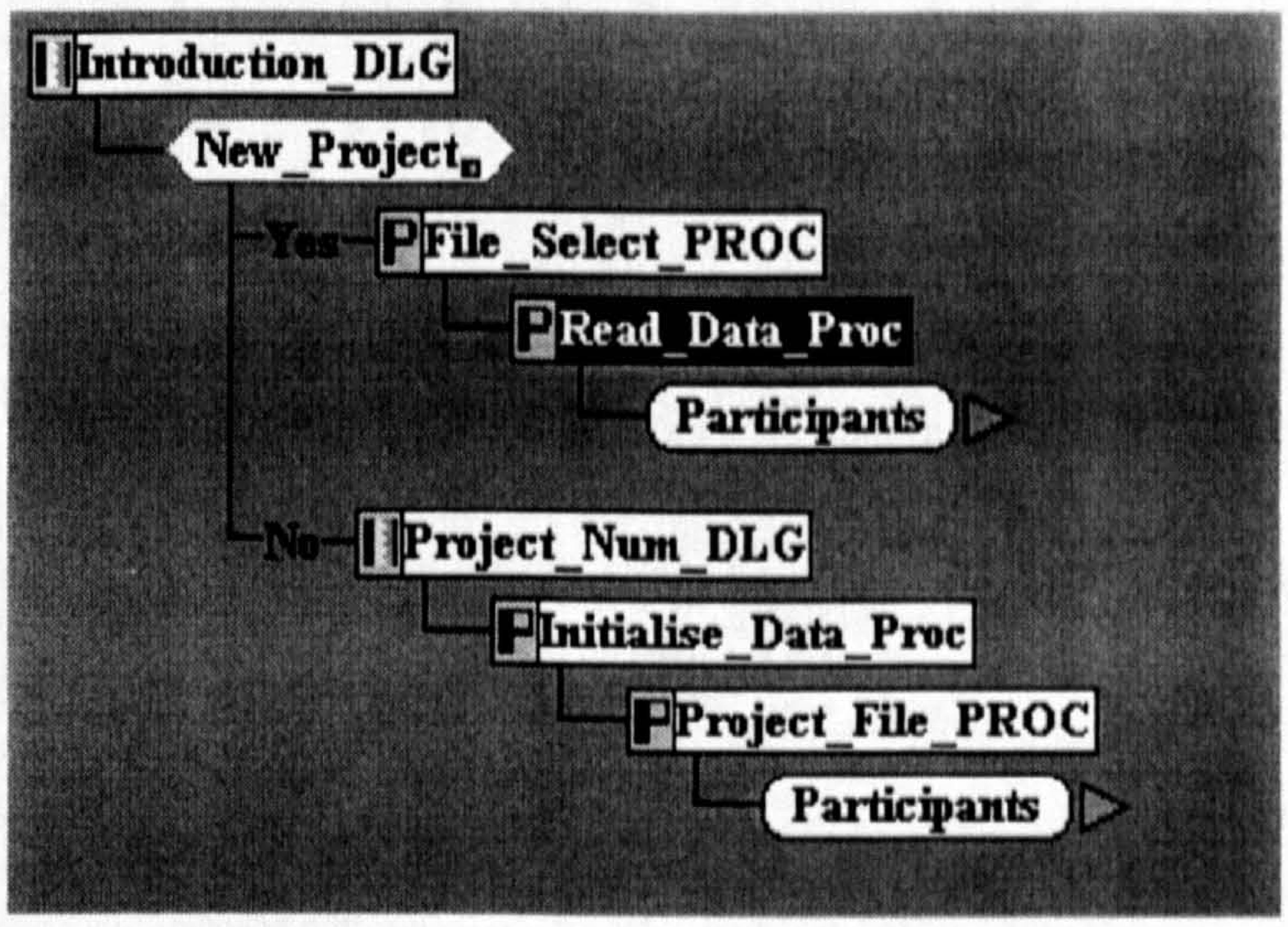


Figure 10.1 Decision tree of 'A_All'

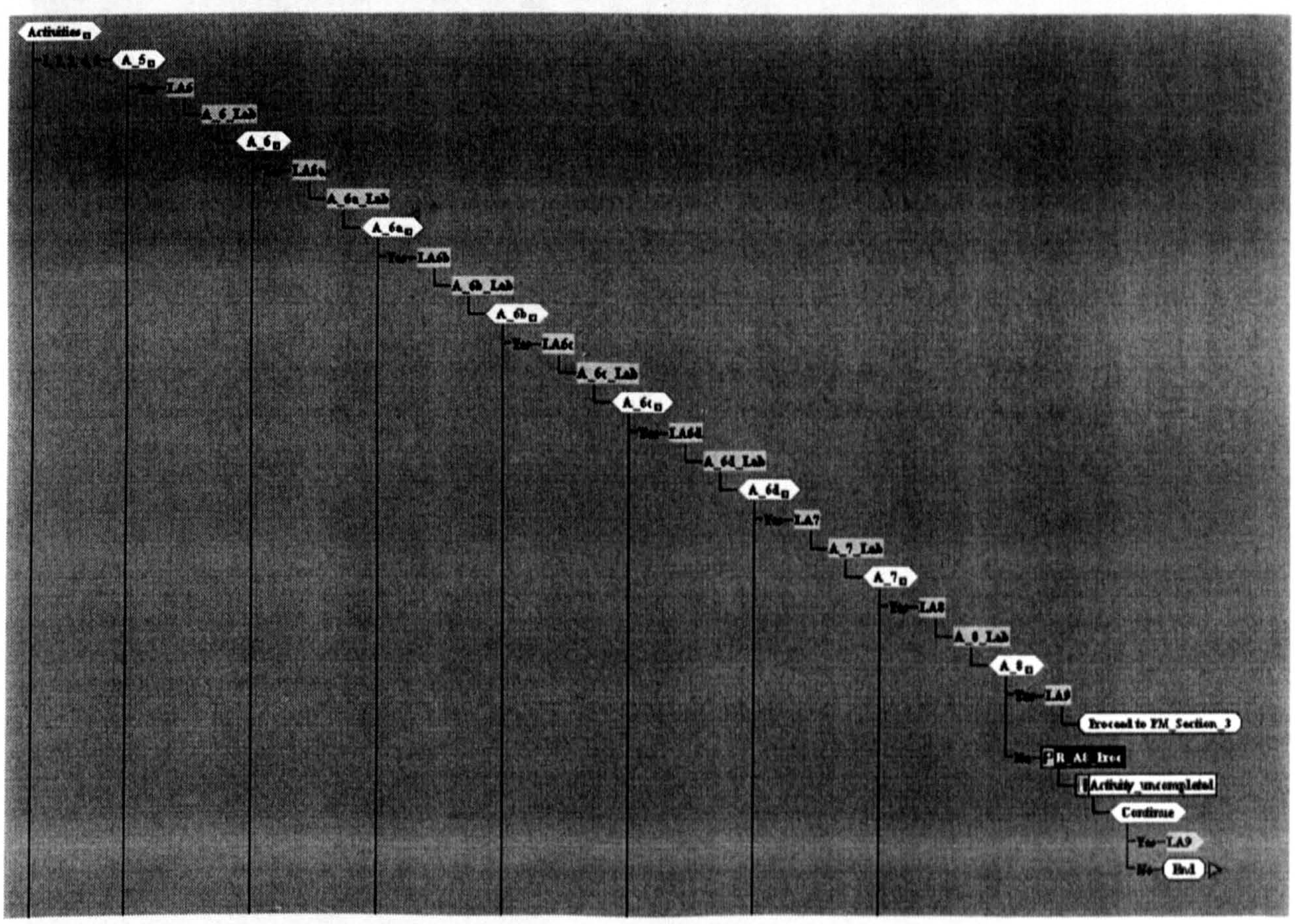


Figure 10.2 Decision tree of activities for project manager – Section 2 (Part 1)

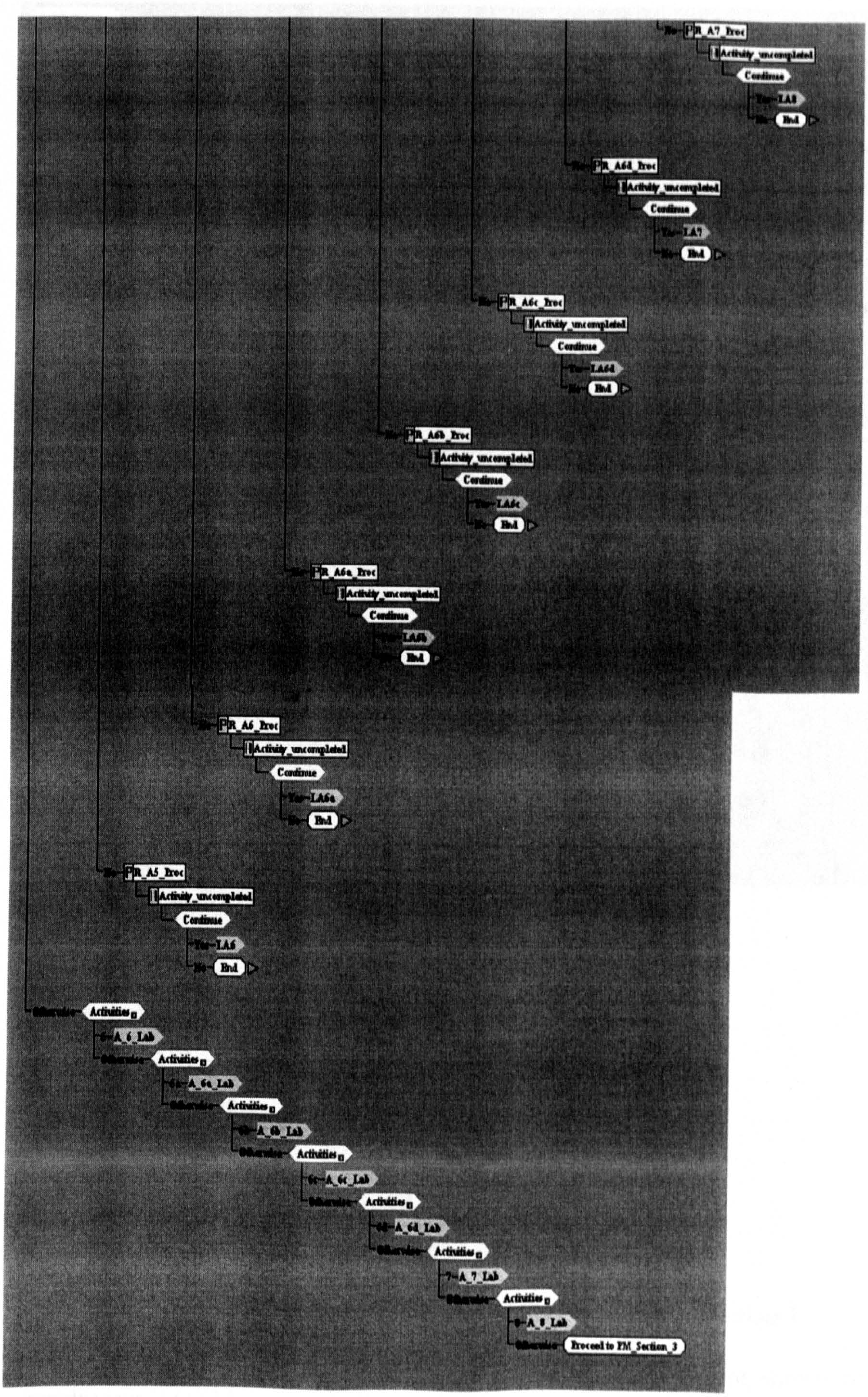


Figure 10.2 Decision tree of activities for project manager – Section 2 (Part 2)

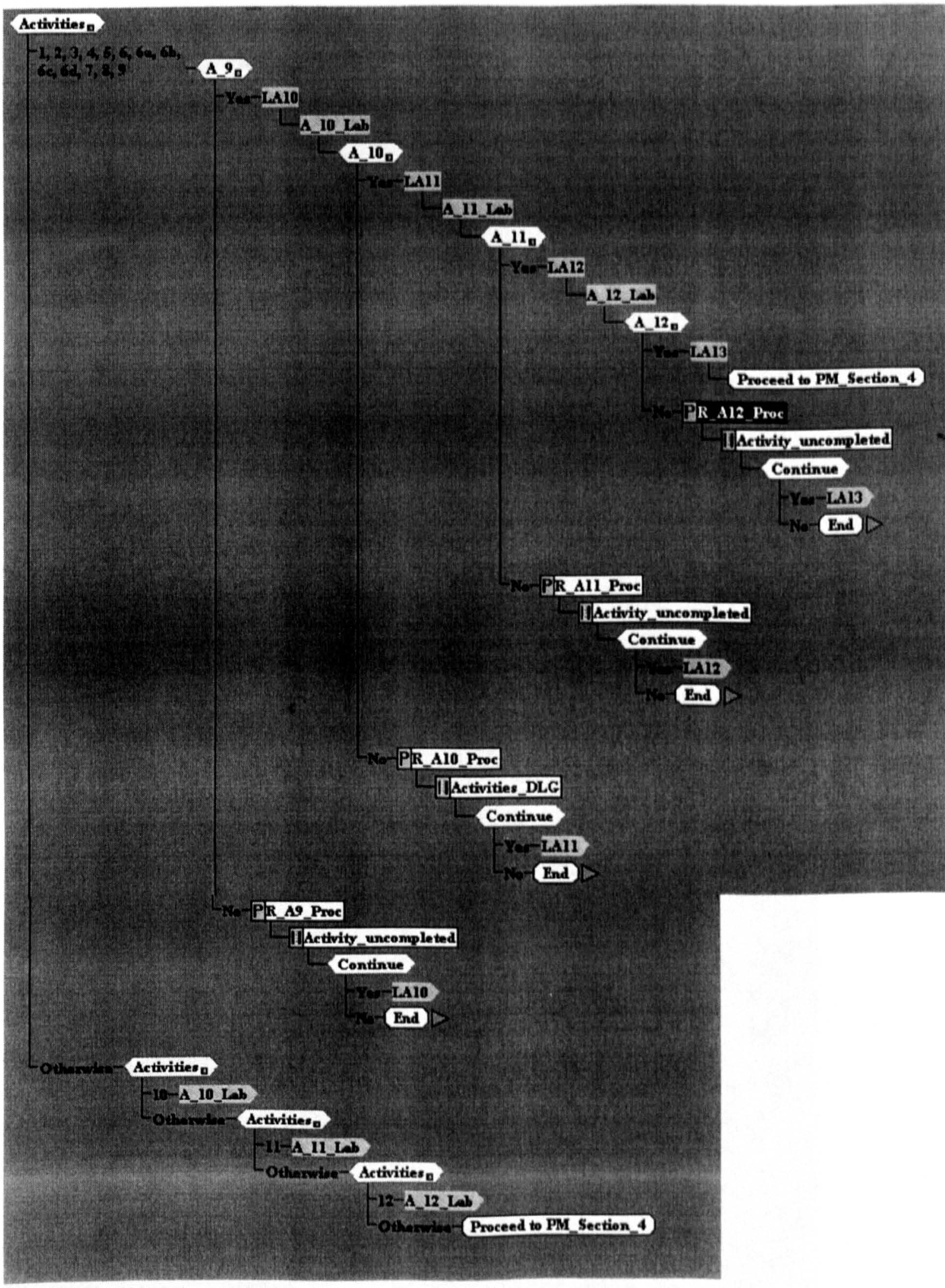


Figure 10.3 Decision tree of activities for project manager – Section 3

The decision of activities for project manager – Section 4 is not shown in the appendix is it is too big.

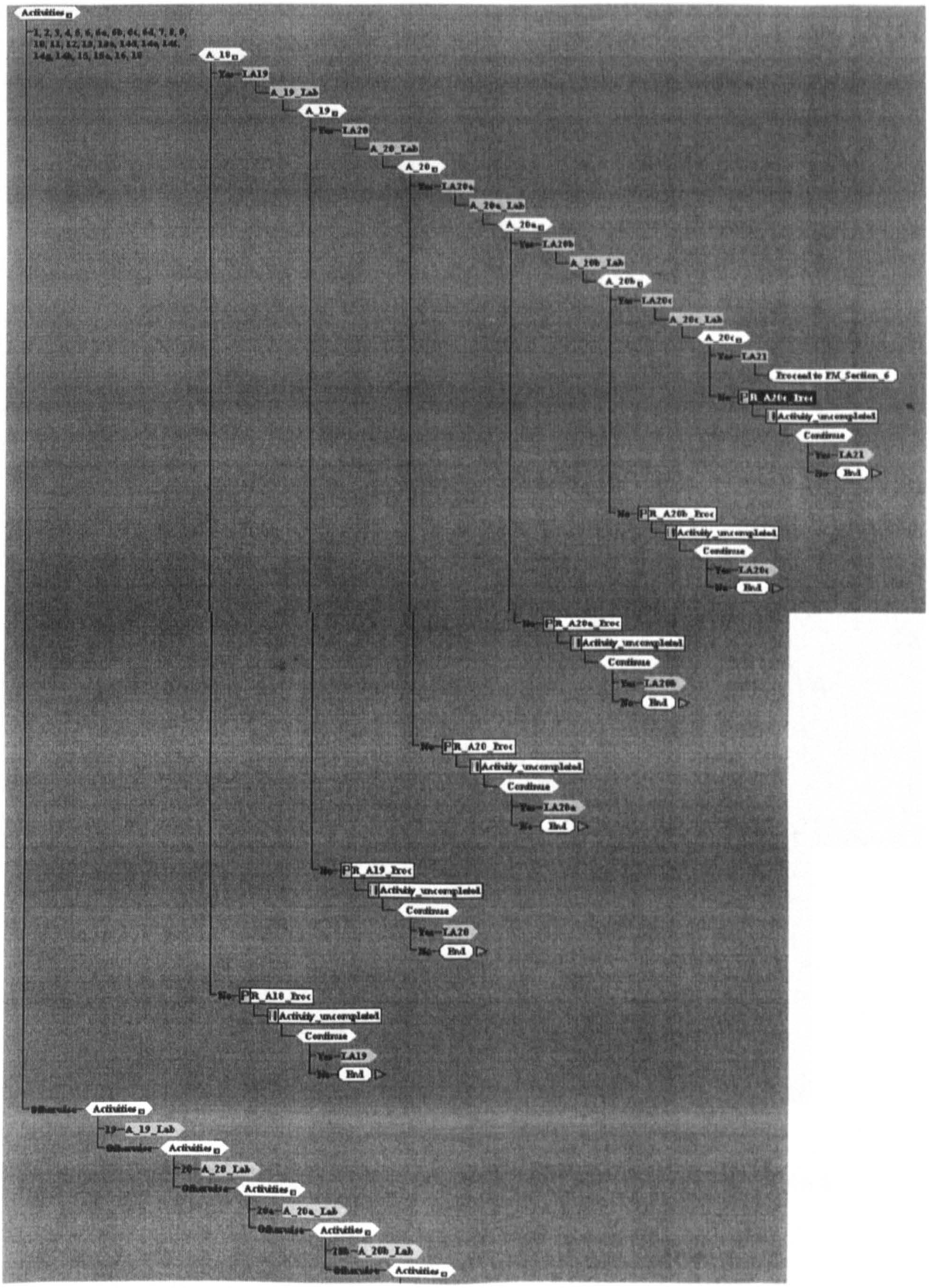


Figure 10.4 Decision tree of activities for project manager – Section 5

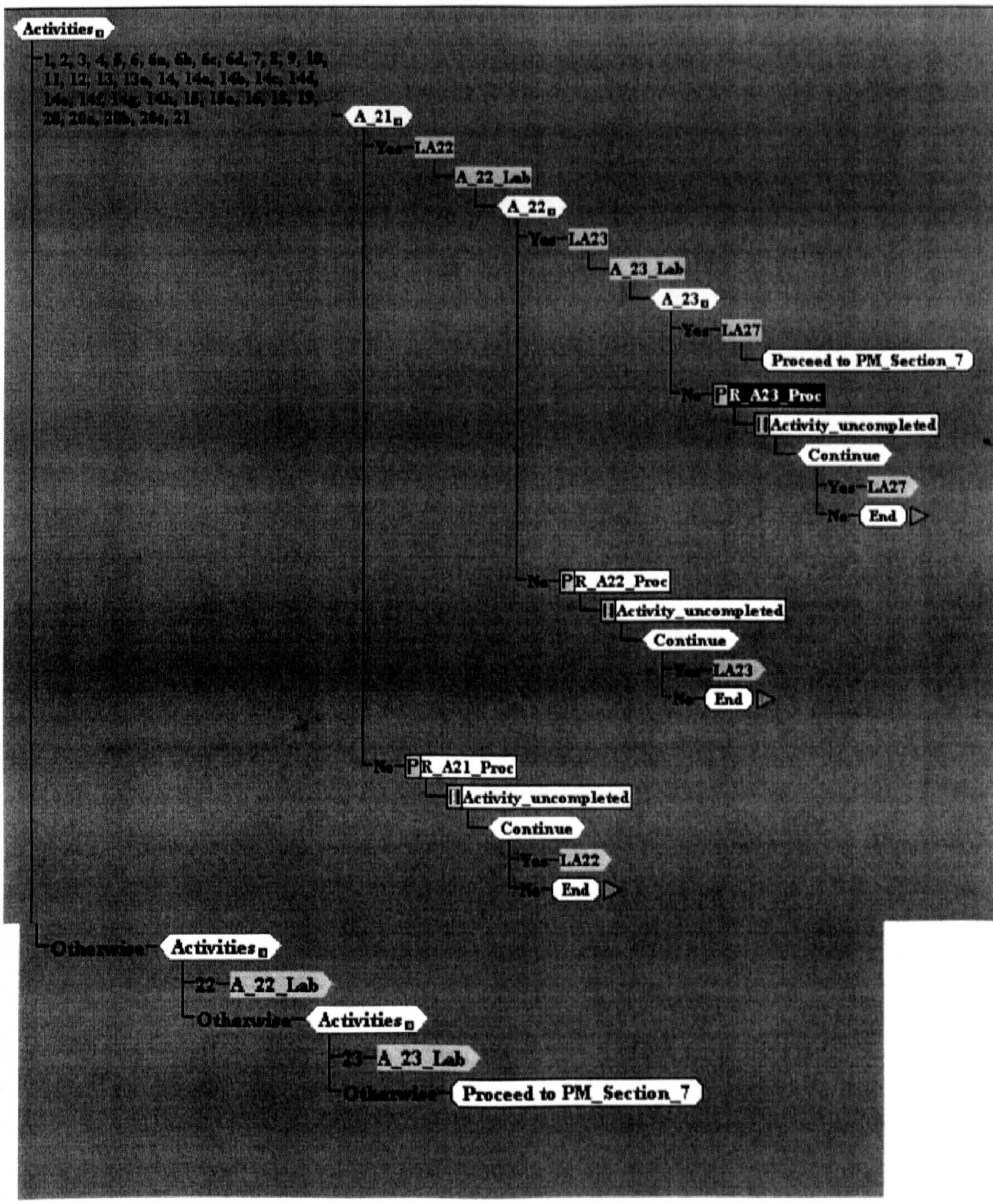


Figure 10.5 Decision tree of activities for project manager – Section 6

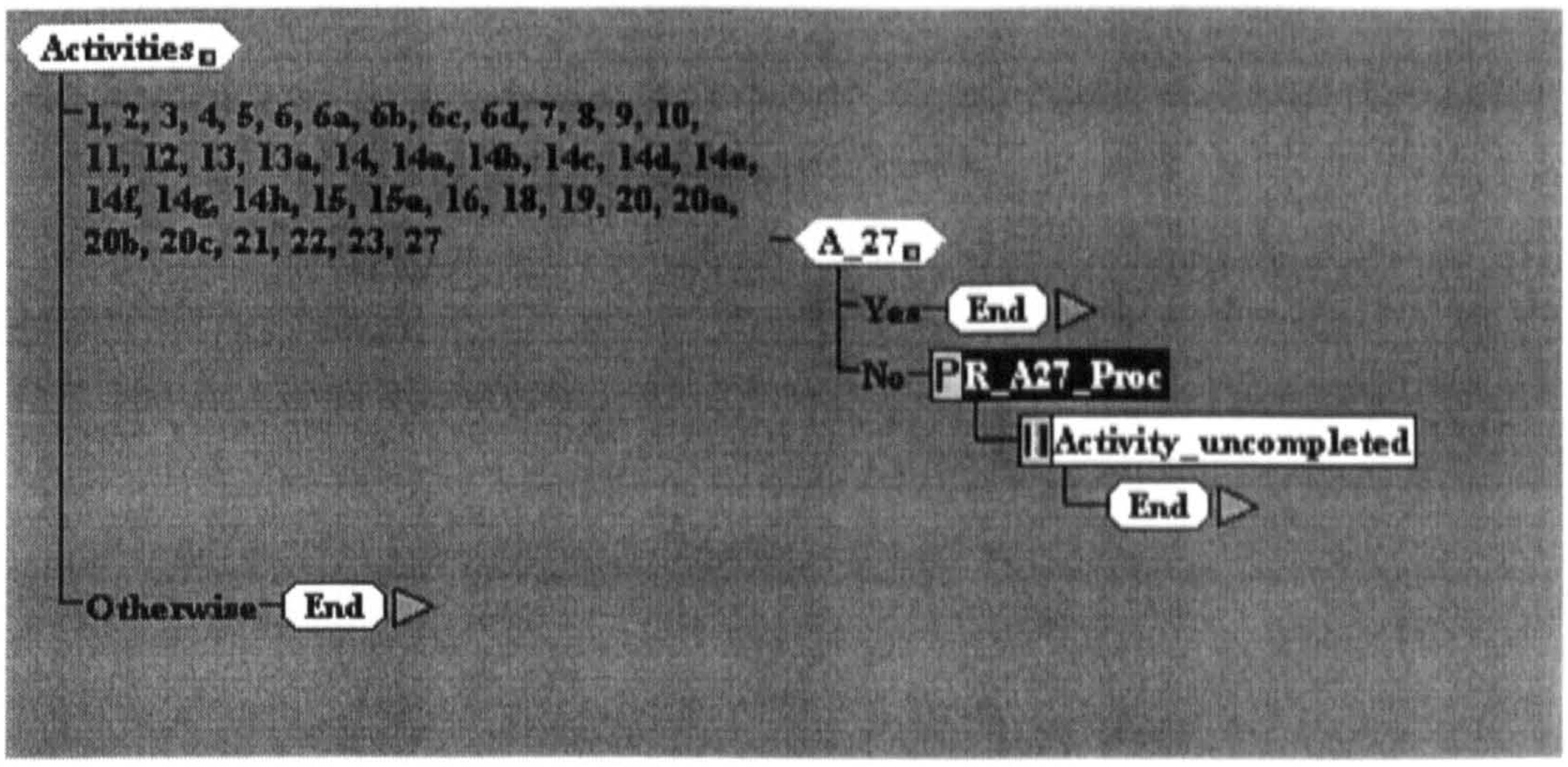


Figure 10.6 Decision tree of activities for project manager – Section 7

The idea for creating the decision trees for other roles is same as 'project manager', so it will not shown in the appendix.

Appendix 11

Decision tree of the file 'A_Main' of updated CONBPS

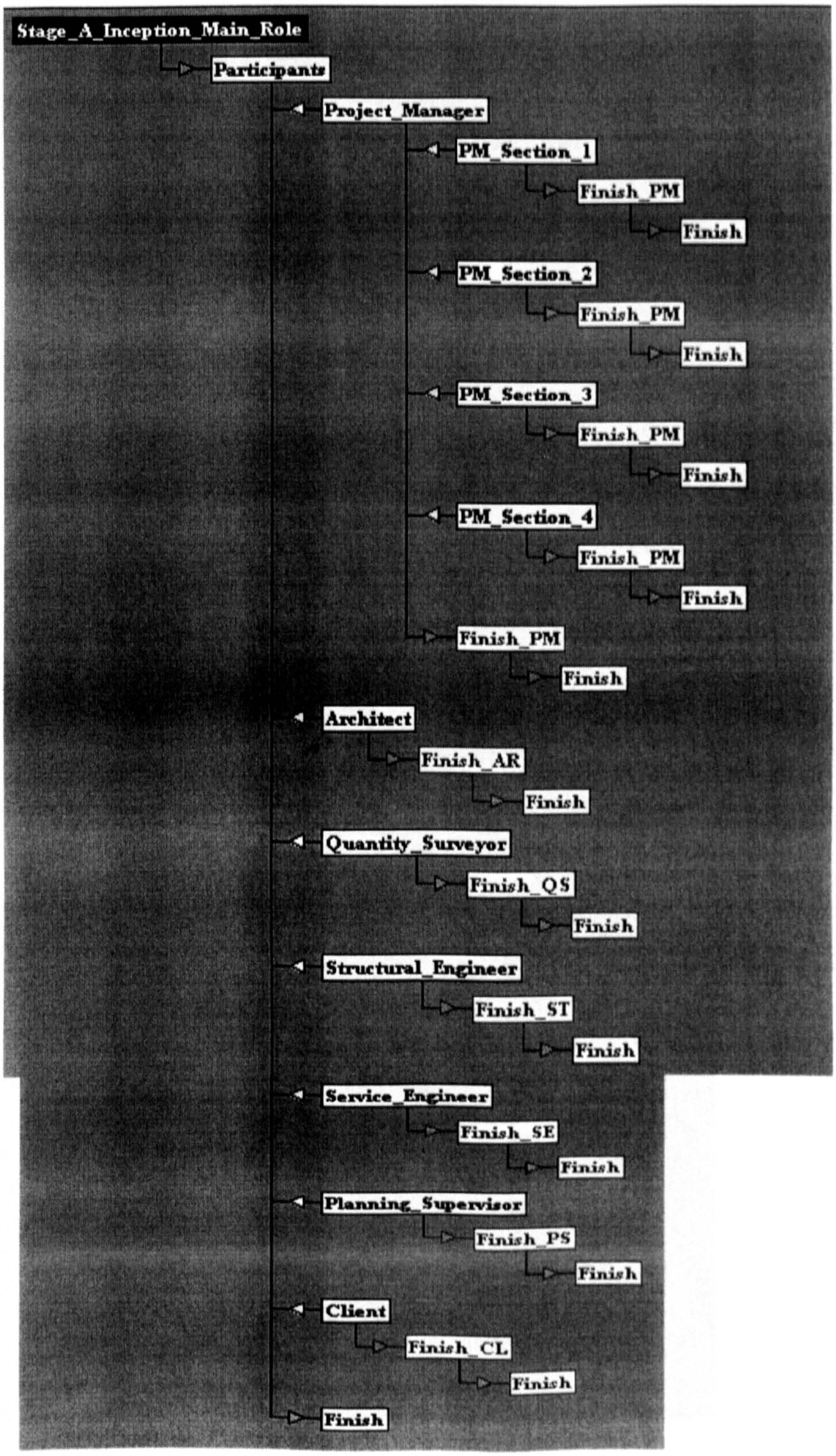


Figure 11.1 Map of 'A_Main'

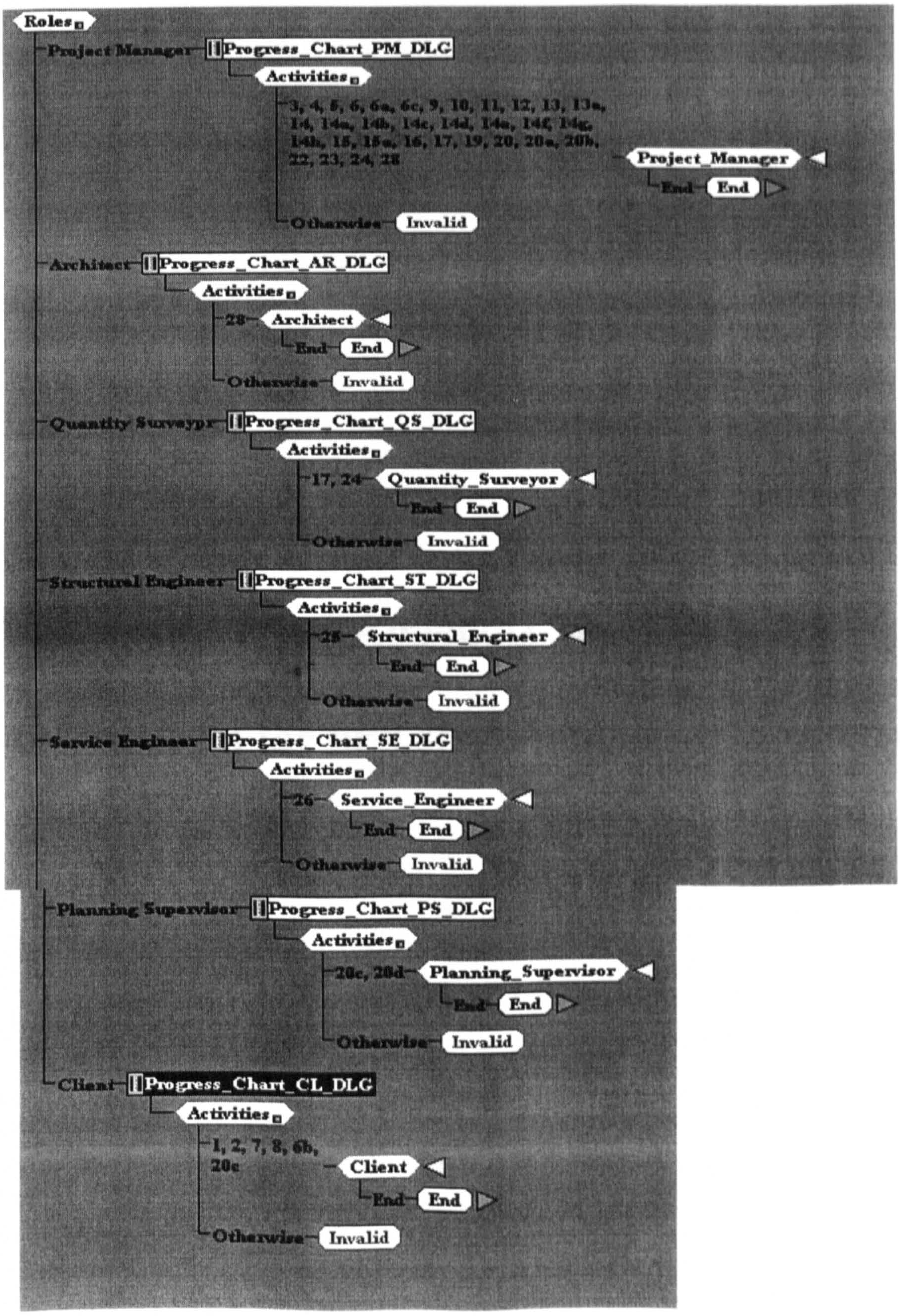


Figure 11.2 Decision tree of 'A_Main' – Participants

The idea for creating the decision trees for the individual participant is same s 'A_All' which has been discussed in appendix 9, so it will not shown in the appendix.

Appendix 12

Information for first stage validation 'interview'

Letters to new participants at first stage validation

Mr. M. W. White
AMEC Design and Management Ltd.
Timothy's Bridge Road
Stratford-upon-Avon
Warwickshire
CV 37 9NJ

Date: 3 July 2000

Dear Mr. White,

Request for interview

I am a Ph.D. research student in the Built Environment Research Unit at the School of Engineering and the Built Environment, University of Wolverhampton.

My research topic is 'Development of a process model for successful building projects'. The aim of this project is to develop a system based on best practice, for use by the client's project manager or construction participants. This can then be used to predict the likelihood of success on the building project. This model focuses on the traditional procurement strategy as it is the procurement strategy which is subject to most criticism.

The sub-aims of the project will be to develop a framework which clearly identifies the roles and responsibilities of the major parties on the building team and identifies the issues within the project cycle which can prove critical to project success viz. completion within time, cost, quality and safety.

Finally, the information will be incorporated into an expert system which can be used by future users before the start of their projects.

The prototype expert system has been developed. The system has been updated after obtaining the comments from construction practitioners. Currently, it is at the evaluation stage of the system.

As this system has identified the roles and responsibilities of structural engineer, I would be pleased if you would be able to agree to have an interview.

In order to facilitate the discussion during the interview, I would like to send you some background information about my project. Could you please comment on the attached information prior to the discussion?

I expect this system will be very useful and beneficial for the future success of construction projects and your kind help would be highly appreciated. Please feel free to contact me if there are any questions.

Thank you for your attention and kind assistance.

Yours faithfully,

Joanna Poon
Research Student
Built Environment Research Unit
School of Engineering and the Built Environment
University of Wolverhampton
Wolverhampton, WV1 1SB, UK
Tel: 01902-322108
Fax: 01902-322743
E-mail: e9817621@wlv.ac.uk

Reply form for new participants at first stage validation

<u>Reply from Mr. M. W. White, AMEC Design and Management Ltd.</u>

Name of respondent: ______________________________

Position: ______________________________

Tel. No.: ______________________________

Fax No.: ______________________________

Do you want to have an interview?

If so, could you please advise a date/ time that is convenient to be interviewed?

Letters to old participants at first stage validation

Mr. PA Hudson
Partner
Frankin and Andrews
Grosvenor House
104 Watergate Street
Chester
CH1 2 LF

Date: 3 July 2000

Dear Mr. Hudson,

Request for interview

I am a Ph.D. research student in the Built Environment Research Unit at the School of Engineering and the Built Environment, University of Wolverhampton.

First please let me express my sincere gratitude for your kind assistance at the interview in January 2000.

My research topic is 'Development of a process model for successful building projects'. The aim of this project is to develop a system based on best practice, for use by the client's project manager and construction participants. This can then be used to predict the likelihood of success on the building project. This model focuses on the traditional procurement strategy as it is the procurement strategy which is subject to most criticism.

Finally, the information will be incorporated into an expert system which can be used by future users before the start of their projects.

Based on the comments that you gave me last time, the prototype of this system has been updated. I would be pleased if you would agree to have an interview.

In order to facilitate the discussion during the interview, I would like to send you some background information about my project. Could you please comment on the attached information before the discussion?

I expect this system will be very useful and beneficial for the future success of construction projects and your kind help would be highly appreciated. Please feel free to contact me if there are any questions.

Thank you for your attention and kind assistance

Yours faithfully,

Joanna Poon
Research Student
Built Environment Research Unit
School of Engineering and the Built Environment
University of Wolverhampton
Wolverhampton, WV1 1SB, UK
Tel: 01902-322108
Fax: 01902-322743
E-mail: e9817621@wlv.ac.uk

Letters to old participants at first stage validation

Reply from Mr. PA Hudson, Frankin and Andrews

Do you want to have an interview?

If so, could you please advise a date/ time that is convenient to be interviewed?

Description of the diagram

The updated framework has two pages. The first page lists the responsible parties and the second page describes the activities in the construction project.

Description of first page

Each box in page one identifies the number of each activity and the role of responsible party. The number identifies the sequence of the activities and the capital letter identifies the 'status' of the responsible parties. For example, if 1A in the column of project manager and 1M in the column of client, this means that the ***major*** responsible party for activity one is client and the project manager acted as ***associated*** role. The major role is the leading participant of that activity; associate participant is the supporting party for that activity.

Sometimes, the construction activities run in parallel basis, like activities 23, 24 and activities 27, 28. These two-pair activities are running coincidentally as the responsible parties for these two-pair activities are different.

Description of second page

Column one is the criteria, which includes

H – Hotspot
'Hotspot' is the critical activities, which the participants should pay special attention to ensure it has been finished before, proceed to next activity.
T – Time
C – Cost
Q – Quality
S - Safety

Column two is the description of the activity. The number identifies the sequence of activity and the text is the description.

Column three is the note. 'CA' means continuous activity. The continuous activities needed to be updated throughout the whole construction stage. 'Sub-1' means sub-heading level 1. For certain activities, they are classified into hierarchy, which consist of main activities and sub activities.

Appendix 13

Information for second stage validation 'case study project'

Information for Pendeford High School Technology Block

Background information

The project started at December 1994 and finished at February 1998.

At December 1994, the client request to investigate the possibility of using 'single building' to accommodate all pupils and staffs as number reduced and both building only used to about 60% at a time.

Following assessment of new area required to existing building, it has been found out that there is the requirement for the formation of a Technology Block

The initial cost estimate for first Technology Block estimated as £660K and the cost for the overall scheme is £1.6M.

The overall project costs was £21K above the Contract figure. On the other hand, the completion date was two weeks ahead of Contract Completion date. Overall, this project is still to be successful.

The detailed project timetable is listed in next table.

Consultants include:

- In-house[1] architect
- In-house quantity surveyor
- In-house electrical service engineer
- In-house mechanical service engineer
- External structural engineer

There is no independent project manager for this project as it is a considerably small project. The architect act dual role as project manager and designer for this project. Also, there is no independent Planning Supervisor.

Client:
Primary client: Education office of Wolverhampton Borough Council
Secondary client: Penedford High School

[1] From Wolverhampton Borough Council

Pendeford High School Technology Block Timetable

Dec 94	Client request to investigate possibility of using 'single building' to accommodate all pupils and staff as number reduced and both building only used to about 60% at a time
Apr 95	Following assessment of new area required to existing building to accommodate all staff and pupils a scheme is prepared for formation of a Technology Block – this is not the only accommodation required as additional Classrooms (8 no.) Administration, increased Staffroom, improved Gymnasium, increased Library, additional Toilets, upgrading of Changing Facilities and increase in Dining area are all required – initial cost estimate for first Technology Block estimated as £660K with in-house M&E Consultants providing budget costs
May 95	Revisions to scheme requested by Client (Education Department)
June 95	Outline Scheme for remainder of School prepared (include new Sports Hall) with a cost estimate of £1.6M
July 95	Technology Block scheme revised and costed at £505K Further revisions to scheme at revised cost of £435K with overall scheme costs of £1.625K
Dec 95	Client requests further development of schemes following consultation with School – Structural Section informed and arrange trial holes and site investigation
Jan 96	Schemes developed further after consultations with School and costed at £462K and £1.295M
Apr 96	Committee approval obtained to develop scheme, produce working drawings, obtain tenders, and commence work on site at an estimated cost of £431K with start on site for October 96 and completion July 97 – Committee approval also given for proposed list of tenders
May 96	Scheme submitted for Planning Approval Request for in-house Mechanical, Electrical and Structural Consultants for project
June 96	Design and working drawings to be provided by all Consultants by the end of July detailed scheme requirements provided by School Frame design proposals provided by Structural Engineer (WS Atkins) Architect programme to complete all working drawings by early August
July 96	Quotations requested from specialist laboratory furniture installers Planning Approval obtained Quantity surveyors to commence 'take off' with tenders to go out early September

Aug 96	Drawings submitted for Educational Constructional Standards approval Pre-tender estimate of £373K + fees (£59K) Pre-tender Health and Safety Plan completed by Quantity surveyor
Sep 96	Tender documents issued
Oct 96	Tenders returned with lowest being £320K Committee Report submitted with tender figures (range of £320K to £352K) Provisional sum had been allowed for the mechanical installation as information not available at tender stage – cost obtained directly from Mechanical Contractors higher than provisional sum and Main Contractor negotiated a lower figure but was still considerably higher than provisional sum – lowest tender revised to £349 to accommodate additional mechanical costs
Nov 96	In-house Planning Supervisor appointed Pre-commencement meeting with all parties Start on-site (18 Nov) – completion due 15 Aug 97 Additional fire escape required by Building Control
Feb 97	Educational Constructional Standards Approval
June 97	Handover of building to School on 30th June – two weeks ahead of Contract Completion date
Feb 98	Making Good Defects certificate issued
Note:	Overall project costs was £21K above the Contract figure which did include Contingency Sums of about £20K Main items which caused the overspend are as follows: Further additional mechanical costs £15.5K Uncharted, deep surface water drainage run £1.5K Uncharted mains electrical cable (specialist work to move) £8K Additional external fire escape £10K Increased foundation design £3.5K

Appendix 14

Verification checklist of file 'Intro'

Introduction

Choose icon 'About'	
Expected Outcome	Go to dialogue box 'About'
Actual Outcome	Go to dialogue box 'About'
Variation	Nil

Choose 'Exit' in icon 'About'	
Expected Outcome	Exit operation of the system
Actual Outcome	Exit operation of the system
Variation	Nil

Choose 'Print' in icon 'About'	
Expected Outcome	Connect to printer and print relevant page
Actual Outcome	Connect to printer and print relevant page
Variation	Nil

Choose 'OK' in icon 'About'	
Expected Outcome	Go back to the introduction screen
Actual Outcome	Go back to the introduction screen
Variation	Nil

Choose icon 'Terminology (1)'	
Expected Outcome	Go to dialogue box 'Terminology (1)'
Actual Outcome	Go to dialogue box 'Terminology (1)'
Variation	Nil

Choose 'Exit' in icon 'Terminology (1)'	
Expected Outcome	Exit operation of the system
Actual Outcome	Exit operation of the system
Variation	Nil

Choose 'Print' in icon 'Terminology (1)'	
Expected Outcome	Connect to printer and print relevant page
Actual Outcome	Connect to printer and print relevant page
Variation	Nil

Choose 'OK' in icon 'Terminology (1)'	
Expected Outcome	Go back to the introduction screen
Actual Outcome	Go back to the introduction screen
Variation	Nil

Choose icon 'Terminology (2)'	
Expected Outcome	Go to dialogue box 'Terminology (2)'
Actual Outcome	Go to dialogue box 'Terminology (2)'
Variation	Nil

Choose 'Exit' in icon 'Terminology (2)'	
Expected Outcome	Exit operation of the system
Actual Outcome	Exit operation of the system
Variation	Nil

Choose 'Print' in icon 'Terminology (2)'	
Expected Outcome	Connect to printer and print relevant page
Actual Outcome	Connect to printer and print relevant page
Variation	Nil

Choose 'OK' in icon 'Terminology (2)'	
Expected Outcome	Go back to the introduction screen
Actual Outcome	Go back to the introduction screen
Variation	Nil

Choose icon 'Description'	
Expected Outcome	Go to dialogue box 'Description'
Actual Outcome	Go to dialogue box 'Description'
Variation	Nil

Choose 'OK' in icon 'Description'	
Expected Outcome	Go back to the introduction screen
Actual Outcome	Go back to the introduction screen
Variation	Nil

Choose icon 'Exit'	
Expected Outcome	Exit operation of the system
Actual Outcome	Exit operation of the system
Variation	Nil

Appendix 15

Verification checklist of file 'CONBPS_A'

CONBPS - A

CONBPS_A	
Proceed	
Expected Outcome	Go to dialogue box 'New Project'
Actual Outcome	Go to dialogue box 'New Project'
Variation	Nil

New Project	
Yes	
Expected Outcome	Open Projects from 'C:\ My Document \ Study \ .txt'
Actual Outcome	Open Projects from 'C:\ My Document \ Study \ .txt'
Variation	Nil
No	
Expected Outcome	Go to dialogue box 'Enter Project Number'
Actual Outcome	Go to dialogue box 'Enter Project Number'
Variation	Nil

Enter Project Number	
Enter Project Number & Proceed	
Expected Outcome	Go to dialogue box 'Activity 1'
Actual Outcome	Go to dialogue box 'Activity 1'
Variation	Nil

	Activity 1	Activity 2	Activity 3	Activity 4
Yes & Proceed				
Expected Outcome	Activity 2	Activity 3	Activity 4	Interim report 1 (see next page for further detail)
Actual Outcome	Activity 2	Activity 3	Activity 4	Interim report 1 (see next page for further detail)
Variation	Nil	Nil	Nil	Nil
No & Proceed				
Expected Outcome	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted
Actual Outcome	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted
Variation	Nil	Nil	Nil	Nil
Choose 'Continue' in Activity uncompleted				
Expected Outcome	Activity 2	Activity 3	Activity 4	Interim report 1 (see next page for further detail)
Actual Outcome	Activity 2	Activity 3	Activity 4	Interim report 1 (see next page for further detail)
Variation	Nil	Nil	Nil	Nil
Choose 'Not continue' in Activity uncompleted				
Expected Outcome	Report	Report	Report	Report
Actual Outcome	Report	Report	Report	Report
Variation	Nil	Nil	Nil	Nil
Processing				
Expected Outcome	Activity 2	Activity 3	Activity 4	Interim report 1 (see next page for further detail)
Actual Outcome	Activity 2	Activity 3	Activity 4	Interim report 1 (see next page for further detail)
Variation	Nil	Nil	Nil	Nil
Back				
Expected Outcome	CONBPS (A)	Activity 1	Activity 2	Activity 3
Actual Outcome	CONBPS (A)	Activity 1	Activity 2	Activity 3
Variation	Nil	Nil	Nil	Nil
Information				
Expected Outcome	Activity 1 (Information)	Activity 2 (Information)	Activity 3 (Information)	Activity 4 (Information)
Actual Outcome	Activity1 (Information)	Activity 2 (Information)	Activity 3 (Information)	Activity 4 (Information)
Variation	Nil	Nil	Nil	Nil
Exit				
Actual Outcome	Report	Report	Report	Report
Expected Outcome	Report	Report	Report	Report
Variation	Nil	Nil	Nil	Nil

If the user finish all activities in section 1, it will go to interim report 1.1.

Expected Outcome	Go to interim report 1.1
Actual Outcome	Go to interim report 1.1
Variation	Nil

If the user does not finish all activities in section 1, then it will go to interim report 1.2.

Expected Outcome	Go to interim report 1.2
Actual Outcome	Go to interim report 1.2
Variation	Nil

In either case, the user press 'OK', then it will go to activity 5.

Expected Outcome	Go to activity 5
Actual Outcome	Go to activity 5
Variation	Nil

In either case, the user press 'Back', then it will go to activity 4.

Expected Outcome	Go to activity 4
Actual Outcome	Go to activity 4
Variation	Nil

In either case, the user press 'Print', then it will print the report.

Expected Outcome	Print
Actual Outcome	Print
Variation	Nil

At the Interim Report 1.2 screen

If the user finish choose the first 'Information' icon, all activities in section 1, then it will go to screen *Information for success factor 'Project Manager'*.

Expected Outcome	Information for success factor 'Project Manager'
Actual Outcome	Information for success factor 'Project Manager'
Variation	Nil

If the user finish choose the second 'Information' icon, then it will go to screen *Information for success factor 'Scope of Project'*.

Expected Outcome	Information for success factor 'Scope of Project'
Actual Outcome	Information for success factor 'Scope of Project'
Variation	Nil

If the user finish choose the third 'Information' icon, then it will go to screen *Information for success factor 'Project Objective'*.

Expected Outcome	Information for success factor 'Project Objective'
Actual Outcome	Information for success factor 'Project Objective'
Variation	Nil

	Activity 5	Activity 6	Activity 6a	Activity 6b
Yes & Proceed				
Expected Outcome	Activity 6	Activity 6a	Activity 6b	Activity 6c
Actual Outcome	Activity 6	Activity 6a	Activity 6b	Activity 6c
Variation	Nil	Nil	Nil	Nil
No & Proceed				
Expected Outcome	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted
Actual Outcome	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted
Variation	Nil	Nil	Nil	Nil
Choose 'Continue' in Activity uncompleted				
Expected Outcome	Activity 6	Activity 6a	Activity 6b	Activity 6c
Actual Outcome	Activity 6	Activity 6a	Activity 6b	Activity 6c
Variation	Nil	Nil	Nil	Nil
Choose 'Not continue' in Activity uncompleted				
Expected Outcome	Report	Report	Report	Report
Actual Outcome	Report	Report	Report	Report
Variation	Nil	Nil	Nil	Nil
Processing				
Expected Outcome	Activity 6	Activity 6a	Activity 6b	Activity 6c
Actual Outcome	Activity 6	Activity 6a	Activity 6b	Activity 6c
Variation	Nil	Nil	Nil	Nil
Back				
Expected Outcome	Interim report 1	Activity 5	Activity 6	Activity 6a
Actual Outcome	Interim report 1	Activity 5	Activity 6	Activity 6a
Variation	Nil	Nil	Nil	Nil
Information				
Expected Outcome	Activity 5 (Information)	Activity 6 (Information)	Activity 6a (Information)	Activity 6b (Information)
Actual Outcome	Activity 5 (Information)	Activity 6 (Information)	Activity 6a (Information)	Activity 6b (Information)
Variation	Nil	Nil	Nil	Nil
Exit				
Actual Outcome	Report	Report	Report	Report
Expected Outcome	Report	Report	Report	Report
Variation	Nil	Nil	Nil	Nil

	Activity 6c	Activity 6d	Activity 7	Activity 8
Yes & Proceed				
Expected Outcome	Activity 6d	Activity 7	Activity 8	Interim report 2 (see next page for further detail)
Actual Outcome	Activity 6d	Activity 7	Activity 8	Interim report 2 (see next page for further detail)
Variation	Nil	Nil	Nil	Nil
No & Proceed				
Expected Outcome	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted
Actual Outcome	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted
Variation	Nil	Nil	Nil	Nil
Choose 'Continue' in Activity uncompleted				
Expected Outcome	Activity 6d	Activity 7	Activity 8	Interim report 2 (see next page for further detail)
Actual Outcome	Activity 6d	Activity 7	Activity 8	Interim report 2 (see next page for further detail)
Variation	Nil	Nil	Nil	Nil
Choose 'Not continue' in Activity uncompleted				
Expected Outcome	Report	Report	Report	Report
Actual Outcome	Report	Report	Report	Report
Variation	Nil	Nil	Nil	Nil
Processing				
Expected Outcome	Activity 6d	Activity 7	Activity 8	Interim report 2 (see next page for further detail)
Actual Outcome	Activity 6d	Activity 7	Activity 8	Interim report 2 (see next page for further detail)
Variation	Nil	Nil	Nil	Nil
Back				
Expected Outcome	Activity 6b	Activity 6c	Activity 6d	Activity 7
Actual Outcome	Activity 6b	Activity 6c	Activity 6d	Activity 7
Variation	Nil	Nil	Nil	Nil
Information				
Expected Outcome	Activity 6c (Information)	Activity 6d (Information)	Activity 7 (Information)	Activity 8 (Information)
Actual Outcome	Activity 6c (Information)	Activity 6d (Information)	Activity 7 (Information)	Activity 8 (Information)
Variation	Nil	Nil	Nil	Nil
Exit				
Actual Outcome	Report	Report	Report	Report
Expected Outcome	Report	Report	Report	Report
Variation	Nil	Nil	Nil	Nil

If the user finish all activities in section 2, then it will go to interim report 2.1.

Expected Outcome	Go to interim report 2.1
Actual Outcome	Go to interim report 2.1
Variation	Nil

If the user does not finish all activities in section 2, then it will go to interim report 2.2.

Expected Outcome	Go to interim report 2.2
Actual Outcome	Go to interim report 2.2
Variation	Nil

In either case, the user press 'OK', then it will go to activity 9.

Expected Outcome	Go to activity 9
Actual Outcome	Go to activity 9
Variation	Nil

In either case, the user press 'Back', then it will go to activity 8.

Expected Outcome	Go to activity 8
Actual Outcome	Go to activity 8
Variation	Nil

In either case, the user press 'Print', then it will print the report.

Expected Outcome	Print
Actual Outcome	Print
Variation	Nil

At the Interim Report 2.2 screen

If the user finish choose the 'Information' icon, all activities in section 1, then it will go to screen *Information for success factor 'Project Team'*.

Expected Outcome	Information for success factor 'Project Team'
Actual Outcome	Information for success factor 'Project Team'
Variation	Nil

	Activity 9	Activity 10	Activity 11	Activity 12
Yes & Proceed				
Expected Outcome	Activity 10	Activity 11	Activity 12	Interim report 3 (see next page for further detail)
Actual Outcome	Activity 10	Activity 11	Activity 12	Interim report 3 (see next page for further detail)
Variation	Nil	Nil	Nil	Nil
No & Proceed				
Expected Outcome	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted
Actual Outcome	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted
Variation	Nil	Nil	Nil	Nil
Choose 'Continue' in Activity uncompleted				
Expected Outcome	Activity 10	Activity 11	Activity 12	Interim report 3 (see next page for further detail)
Actual Outcome	Activity 10	Activity 11	Activity 12	Interim report 3 (see next page for further detail)
Variation	Nil	Nil	Nil	Nil
Choose 'Not continue' in Activity uncompleted				
Expected Outcome	Report	Report	Report	Report
Actual Outcome	Report	Report	Report	Report
Variation	Nil	Nil	Nil	Nil
Processing				
Expected Outcome	Activity 10	Activity 11	Activity 12	Interim report 3 (see next page for further detail)
Actual Outcome	Activity 10	Activity 11	Activity 12	Interim report 3 (see next page for further detail)
Variation	Nil	Nil	Nil	Nil
Back				
Expected Outcome	Interim report 2	Activity 9	Activity 10	Activity 11
Actual Outcome	Interim report 2	Activity 9	Activity 10	Activity 11
Variation	Nil	Nil	Nil	Nil
Information				
Expected Outcome	Activity 9 (Information)	Activity 10 (Information)	Activity 11 (Information)	Activity 12 (Information)
Actual Outcome	Activity 9 (Information)	Activity 10 (Information)	Activity 11 (Information)	Activity 12 (Information)
Variation	Nil	Nil	Nil	Nil
Exit				
Actual Outcome	Report	Report	Report	Report
Expected Outcome	Report	Report	Report	Report
Variation	Nil	Nil	Nil	Nil

If the user finish all activities in section 3, then it will go to interim report 3.1.

Expected Outcome	Go to interim report 3.1
Actual Outcome	Go to interim report 3.1
Variation	Nil

If the user does not finish all activities in section 3, then it will go to interim report 3.2.

Expected Outcome	Go to interim report 3.2
Actual Outcome	Go to interim report 3.2
Variation	Nil

In either case, the user press 'OK', then it will go to activity 13.

Expected Outcome	Go to activity 13
Actual Outcome	Go to activity 13
Variation	Nil

In either case, the user press 'Back', then it will go to activity 12.

Expected Outcome	Go to activity 12
Actual Outcome	Go to activity 12
Variation	Nil

In either case, the user press 'Print', then it will print the report.

Expected Outcome	Print
Actual Outcome	Print
Variation	Nil

At the Interim Report 3.2 screen

If the user finish choose the first 'Information' icon, all activities in section 1, then it will go to screen *Information for success factor 'Scope of Project'.*

Expected Outcome	Information for success factor 'Scope of Project'
Actual Outcome	Information for success factor 'Scope of Project'
Variation	Nil

If the user finish choose the second 'Information' icon, then it will go to screen *Information for success factor 'Communication and Information Management'.*

Expected Outcome	Information for success factor 'Communication and Information Management'
Actual Outcome	Information for success factor ''Communication and Information Management'
Variation	Nil

	Activity 13	Activity 13a	Activity 14	Activity 14a
Yes & Proceed				
Expected Outcome	Activity 13a	Activity 14	Activity 14a	Activity 14b
Actual Outcome	Activity 13a	Activity 14	Activity 14a	Activity 14b
Variation	Nil	Nil	Nil	Nil
No & Proceed				
Expected Outcome	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted
Actual Outcome	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted
Variation	Nil	Nil	Nil	Nil
Choose 'Continue' in Activity uncompleted				
Expected Outcome	Activity 13a	Activity 14	Activity 14a	Activity 14b
Actual Outcome	Activity 13a	Activity 14	Activity 14a	Activity 14b
Variation	Nil	Nil	Nil	Nil
Choose 'Not continue' in Activity uncompleted				
Expected Outcome	Report	Report	Report	Report
Actual Outcome	Report	Report	Report	Report
Variation	Nil	Nil	Nil	Nil
Processing				
Expected Outcome	Activity 13a	Activity 14	Activity 14a	Activity 14b
Actual Outcome	Activity 13a	Activity 14	Activity 14a	Activity 14b
Variation	Nil	Nil	Nil	Nil
Back				
Expected Outcome	Interim report 3	Activity 13	Activity 13a	Activity 14
Actual Outcome	Interim report 3	Activity 13	Activity 13a	Activity 14
Variation	Nil	Nil	Nil	Nil
Information				
Expected Outcome	Activity 13 (Information)	Activity 13a (Information)	Activity 14 (Information)	Activity 14a (Information)
Actual Outcome	Activity 13 (Information)	Activity 13a (Information)	Activity 14 (Information)	Activity 14a (Information)
Variation	Nil	Nil	Nil	Nil
Exit				
Actual Outcome	Report	Report	Report	Report
Expected Outcome	Report	Report	Report	Report
Variation	Nil	Nil	Nil	Nil

	Activity 14b	Activity 14c		
Yes & Proceed				
Expected Outcome	Activity 14c	Interim report 4a (see next page for further detail)		
Actual Outcome	Activity 14c	Interim report 4a (see next page for further detail)		
Variation	Nil	Nil		
No & Proceed				
Expected Outcome	Activity Uncompleted	Activity Uncompleted		
Actual Outcome	Activity Uncompleted	Activity Uncompleted		
Variation	Nil	Nil		
Choose 'Continue' in Activity uncompleted				
Expected Outcome	Activity 14c	Interim report 4a (see next page for further detail)		
Actual Outcome	Activity 14c	Interim report 4a (see next page for further detail)		
Variation	Nil	Nil		
Choose 'Not continue' in Activity uncompleted				
Expected Outcome	Report	Report		
Actual Outcome	Report	Report		
Variation	Nil	Nil		
Processing				
Expected Outcome	Activity 14c	Interim report 4a (see next page for further detail)		
Actual Outcome	Activity 14c	Interim report 4a (see next page for further detail)		
Variation	Nil	Nil		
Back				
Expected Outcome	Activity 14a	Activity 14b		
Actual Outcome	Activity 14a	Activity 14b		
Variation	Nil	Nil		
Information				
Expected Outcome	Activity 14b (Information)	Activity 14c (Information)		
Actual Outcome	Activity 14b (Information)	Activity 14c (Information)		
Variation	Nil	Nil		
Exit				
Actual Outcome	Report	Report		
Expected Outcome	Report	Report		
Variation	Nil	Nil		

If the user finish all activities in section 4a then it will go to interim report 4a.1.

Expected Outcome	Go to interim report 4a.1
Actual Outcome	Go to interim report 4a.1
Variation	Nil

If the user does not finish all activities in section 4a, then it will go to interim report 4a.2.

Expected Outcome	Go to interim report 4a.2
Actual Outcome	Go to interim report 4a.2
Variation	Nil

In either case, the user press 'OK', then it will go to activity 14d.

Expected Outcome	Go to activity 14d
Actual Outcome	Go to activity 14d
Variation	Nil

In either case, the user press 'Back', then it will go to activity 14c.

Expected Outcome	Go to activity 14c
Actual Outcome	Go to activity 14c
Variation	Nil

In either case, the user press 'Print', then it will print the report.

Expected Outcome	Print
Actual Outcome	Print
Variation	Nil

At the Interim Report 4a.2 screen

If the user finish choose the first 'Information' icon, all activities in section 1, then it will go to screen *Information for success factor 'Control'*.

Expected Outcome	Information for success factor 'Control'
Actual Outcome	Information for success factor 'Control'
Variation	Nil

	Activity 14d	Activity 14e	Activity 14f	Activity 14g
Yes & Proceed				
Expected Outcome	Activity 14e	Activity 14f	Activity 14g	Activity 14h
Actual Outcome	Activity 14e	Activity 14f	Activity 14g	Activity 14h
Variation	Nil	Nil	Nil	Nil
No & Proceed				
Expected Outcome	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted
Actual Outcome	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted
Variation	Nil	Nil	Nil	Nil
Choose 'Continue' in Activity uncompleted				
Expected Outcome	Activity 14e	Activity 14f	Activity 14g	Activity 14h
Actual Outcome	Activity 14e	Activity 14f	Activity 14g	Activity 14h
Variation	Nil	Nil	Nil	Nil
Choose 'Not continue' in Activity uncompleted				
Expected Outcome	Report	Report	Report	Report
Actual Outcome	Report	Report	Report	Report
Variation	Nil	Nil	Nil	Nil
Processing				
Expected Outcome	Activity 14e	Activity 14f	Activity 14g	Activity 14h
Actual Outcome	Activity 14e	Activity 14f	Activity 14g	Activity 14h
Variation	Nil	Nil	Nil	Nil
Back				
Expected Outcome	Interim report 4a	Activity 14d	Activity14e	Activity 14f
Actual Outcome	Interim report 4a	Activity 14d	Activity14e	Activity 14f
Variation	Nil	Nil	Nil	Nil
Information				
Expected Outcome	Activity 14d (Information)	Activity 14e (Information)	Activity 14f (Information)	Activity 14g (Information)
Actual Outcome	Activity 14d (Information)	Activity 14e (Information)	Activity 14f (Information)	Activity 14g (Information)
Variation	Nil	Nil	Nil	Nil
Exit				
Actual Outcome	Report	Report	Report	Report
Expected Outcome	Report	Report	Report	Report
Variation	Nil	Nil	Nil	Nil

	Activity 14h	Activity 15	Activity 15a	Activity 16
Yes & Proceed				
Expected Outcome	Activity 15	Activity 15a	Activity 16	Interim report 4b (see next page for further detail)
Actual Outcome	Activity 15	Activity 15a	Activity 16	Interim report 4b (see next page for further detail)
Variation	Nil	Nil	Nil	Nil
No & Proceed				
Expected Outcome	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted
Actual Outcome	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted
Variation	Nil	Nil	Nil	Nil
Choose 'Continue' in Activity uncompleted				
Expected Outcome	Activity 15	Activity 15a	Activity 16	Interim report 4b (see next page for further detail)
Actual Outcome	Activity 15	Activity 15a	Activity 16	Interim report 4b (see next page for further detail)
Variation	Nil	Nil	Nil	Nil
Choose 'Not continue' in Activity uncompleted				
Expected Outcome	Report	Report	Report	Report
Actual Outcome	Report	Report	Report	Report
Variation	Nil	Nil	Nil	Nil
Processing				
Expected Outcome	Activity 15	Activity 15a	Activity 16	Interim report 4b (see next page for further detail)
Actual Outcome	Activity 15	Activity 15a	Activity 16	Interim report 4b (see next page for further detail)
Variation	Nil	Nil	Nil	Nil
Back				
Expected Outcome	Activity 14g	Activity 14h	Activity 15	Activity 15a
Actual Outcome	Activity 14g	Activity 14h	Activity 15	Activity 15a
Variation	Nil	Nil	Nil	Nil
Information				
Expected Outcome	Activity 14h (Information)	Activity 15 (Information)	Activity 15a (Information)	Activity 16 (Information)
Actual Outcome	Activity 14h (Information)	Activity 15 (Information)	Activity 15a (Information)	Activity 16 (Information)
Variation	Nil	Nil	Nil	Nil
Exit				
Actual Outcome	Report	Report	Report	Report
Expected Outcome	Report	Report	Report	Report
Variation	Nil	Nil	Nil	Nil

If the user finish all activities in section 4b, then it will go to interim report 4b.1.

Expected Outcome	Go to interim report 4b.1
Actual Outcome	Go to interim report 4b.1
Variation	Nil

If the user does not finish all activities in section 4b, then it will go to interim report 4b.1.

Expected Outcome	Go to interim report 4b.1
Actual Outcome	Go to interim report 4b.1
Variation	Nil

In either case, the user press 'OK', then it will go to activity 17.

Expected Outcome	Go to activity 17
Actual Outcome	Go to activity 17
Variation	Nil

In either case, the user press 'Back', then it will go to activity 16.

Expected Outcome	Go to activity 16
Actual Outcome	Go to activity 16
Variation	Nil

In either case, the user press 'Print', then it will print the report.

Expected Outcome	Print
Actual Outcome	Print
Variation	Nil

	Activity 17	Activity 18	Activity 19	Activity 20
Yes & Proceed				
Expected Outcome	Activity 18	Activity 19	Activity 20	Activity 20a
Actual Outcome	Activity 18	Activity 19	Activity 20	Activity 20a
Variation	Nil	Nil	Nil	Nil
No & Proceed				
Expected Outcome	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted
Actual Outcome	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted
Variation	Nil	Nil	Nil	Nil
Choose 'Continue' in Activity uncompleted				
Expected Outcome	Activity 18	Activity 19	Activity 20	Activity 20a
Actual Outcome	Activity 18	Activity 19	Activity 20	Activity 20a
Variation	Nil	Nil	Nil	Nil
Choose 'Not continue' in Activity uncompleted				
Expected Outcome	Report	Report	Report	Report
Actual Outcome	Report	Report	Report	Report
Variation	Nil	Nil	Nil	Nil
Processing				
Expected Outcome	Activity 18	Activity 19	Activity 20	Activity 20a
Actual Outcome	Activity 18	Activity 19	Activity 20	Activity 20a
Variation	Nil	Nil	Nil	Nil
Back				
Expected Outcome	Interim report 4b	Activity 17	Activity 18	Activity 19
Actual Outcome	Interim report 4b	Activity 17	Activity 18	Activity 19
Variation	Nil	Nil	Nil	Nil
Information				
Expected Outcome	Activity 17 (Information)	Activity 18 (Information)	Activity 19 (Information)	Activity 20 (Information)
Actual Outcome	Activity 17 (Information)	Activity 18 (Information)	Activity 19 (Information)	Activity 20 (Information)
Variation	Nil	Nil	Nil	Nil
Exit				
Actual Outcome	Report	Report	Report	Report
Expected Outcome	Report	Report	Report	Report
Variation	Nil	Nil	Nil	Nil

	Activity 20a	Activity 20b	Activity 20c	Activity 20d
Yes & Proceed				
Expected Outcome	Activity 20b	Activity 20c	Activity 20d	Interim report 5 (see next page for further detail)
Actual Outcome	Activity 20b	Activity 20c	Activity 20d	Interim report 5 (see next page for further detail)
Variation	Nil	Nil	Nil	Nil
No & Proceed				
Expected Outcome	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted
Actual Outcome	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted
Variation	Nil	Nil	Nil	Nil
Choose 'Continue' in Activity uncompleted				
Expected Outcome	Activity 20b	Activity 20c	Activity 20d	Interim report 5 (see next page for further detail)
Actual Outcome	Activity 20b	Activity 20c	Activity 20d	Interim report 5 (see next page for further detail)
Variation	Nil	Nil	Nil	Nil
Choose 'Not continue' in Activity uncompleted				
Expected Outcome	Report	Report	Report	Report
Actual Outcome	Report	Report	Report	Report
Variation	Nil	Nil	Nil	Nil
Processing				
Expected Outcome	Activity 20b	Activity 20c	Activity 20d	Interim report 5 (see next page for further detail)
Actual Outcome	Activity 20b	Activity 20c	Activity 20d	Interim report 5 (see next page for further detail)
Variation	Nil	Nil	Nil	Nil
Back				
Expected Outcome	Activity 20	Activity 20a	Activity 20b	Activity 20c
Actual Outcome	Activity 20	Activity 20a	Activity 20b	Activity 20c
Variation	Nil	Nil	Nil	Nil
Information				
Expected Outcome	Activity 20a (Information)	Activity 20b (Information)	Activity 20c (Information)	Activity 20d (Information)
Actual Outcome	Activity 20a (Information)	Activity 20b (Information)	Activity 20c (Information)	Activity 20d (Information)
Variation	Nil	Nil	Nil	Nil
Exit				
Actual Outcome	Report	Report	Report	Report
Expected Outcome	Report	Report	Report	Report
Variation	Nil	Nil	Nil	Nil

If the user finish all activities in section 5, then it will go to interim report 5.1.

Expected Outcome	Go to interim report 5.1
Actual Outcome	Go to interim report 5.1
Variation	Nil

If the user does not finish all activities in section 5, then it will go to interim report 5.2.

Expected Outcome	Go to interim report 5.2
Actual Outcome	Go to interim report 5.2
Variation	Nil

In either case, the user press 'OK', then it will go to activity 21.

Expected Outcome	Go to activity 21
Actual Outcome	Go to activity 21
Variation	Nil

In either case, the user press 'back', then it will go to activity 20d.

Expected Outcome	Go to activity 20d
Actual Outcome	Go to activity 20d
Variation	Nil

In either case, the user press 'Print', then it will print the report.

Expected Outcome	Print
Actual Outcome	Print
Variation	Nil

At the Interim Report 5.2 screen

If the user finish choose the 'Information' icon, all activities in section 1, then it will go to screen *Information for success factor 'Health and Safety'*.

Expected Outcome	Information for success factor 'Health and Safety'
Actual Outcome	Information for success factor 'Health and Safety'
Variation	Nil

	Activity 21	Activity 22		
Yes & Proceed				
Expected Outcome	Activity 22	Choose either activity 23 or 24		
Actual Outcome	Activity 22	Choose either activity 23 or 24		
Variation	Nil	Nil		
No & Proceed				
Expected Outcome	Activity Uncompleted	Activity Uncompleted		
Actual Outcome	Activity Uncompleted	Activity Uncompleted		
Variation	Nil	Nil		
Choose 'Continue' in Activity uncompleted				
Expected Outcome	Activity 22	Choose either activity 23 or 24		
Actual Outcome	Activity 22	Choose either activity 23 or 24		
Variation	Nil	Nil		
Choose 'Not continue' in Activity uncompleted				
Expected Outcome	Report	Report		
Actual Outcome	Report	Report		
Variation	Nil	Nil		
Processing				
Expected Outcome	Activity 22	Choose either activity 23 or 24		
Actual Outcome	Activity 22	Choose either activity 23 or 24		
Variation	Nil	Nil		
Back				
Expected Outcome	Interim report 5	Activity 21		
Actual Outcome	Interim report 5	Activity 21		
Variation	Nil	Nil		
Information				
Expected Outcome	Activity 21 (Information)	Activity 22 (Information)		
Actual Outcome	Activity 21 (Information)	Activity 22 (Information)		
Variation	Nil	Nil		
Exit				
Actual Outcome	Report	Report		
Expected Outcome	Report	Report		
Variation	Nil	Nil		

Choose either activity 23 or 24

Choose 23	
Actual outcome	Go to activity 23
Expected Outcome	Go to activity 23
Variation	Nil
Choose 24	
Actual outcome	Go to activity 24
Expected Outcome	Go to activity 24
Variation	Nil

	Activity 23	Activity 24		
Yes & Proceed				
Expected Outcome	Activity 25	Interim report 6 (see next page for further detail)		
Actual Outcome	Activity 25	Interim report 6 (see next page for further detail)		
Variation	Nil	Nil		
No & Proceed				
Expected Outcome	Activity Uncompleted	Activity Uncompleted		
Actual Outcome	Activity Uncompleted	Activity Uncompleted		
Variation	Nil	Nil		
Choose 'Continue' in Activity uncompleted				
Expected Outcome	Activity 25	Interim report 6 (see next page for further detail)		
Actual Outcome	Activity 25	Interim report 6 (see next page for further detail)		
Variation	Nil	Nil		
Choose 'Not continue' in Activity uncompleted				
Expected Outcome	Report	Report		
Actual Outcome	Report	Report		
Variation	Nil	Nil		
Processing				
Expected Outcome	Activity 25	Interim report 6 (see next page for further detail)		
Actual Outcome	Activity 25	Interim report 6 (see next page for further detail)		
Variation	Nil	Nil		
Back				
Expected Outcome	Choose either activity 23 or 24	Choose either activity 23 or 24		
Actual Outcome	Choose either activity 23 or 24	Choose either activity 23 or 24		
Variation	Nil	Nil		
Information				
Expected Outcome	Activity 23 (Information)	Activity 24 (Information)		
Actual Outcome	Activity 23 (Information)	Activity 24 (Information)		
Variation	Nil	Nil		
Exit				
Actual Outcome	Report	Report		
Expected Outcome	Report	Report		
Variation	Nil	Nil		

If the user finish all activities in section 6, then it will go to interim report 6.1.

Expected Outcome	Go to interim report 6.1
Actual Outcome	Go to interim report 6.1
Variation	Nil

If the user does not finish all activities in section 6, then it will go to interim report 6.2.

Expected Outcome	Go to interim report 6.2
Actual Outcome	Go to interim report 6.2
Variation	Nil

In either case, the user press 'OK', then it will go to activity 25.

Expected Outcome	Go to activity 25
Actual Outcome	Go to activity 25
Variation	Nil

If the user choose activity 23 previously, it will go back to activity 23 if they press 'Back'.

Expected Outcome	Go to activity 23
Actual Outcome	Go to activity 23
Variation	Nil

If the user choose activity 24 previously, it will go back to activity 24 if they press 'Back'.

Expected Outcome	Go to activity 24
Actual Outcome	Go to activity 24
Variation	Nil

In either case, the user press 'Print', then it will print the report.

Expected Outcome	Print
Actual Outcome	Print
Variation	Nil

	Activity 25	Activity 26
Yes & Proceed		
Expected Outcome	Activity 26	Choose either activity 27 or 28
Actual Outcome	Activity 26	Choose either activity 27 or 28
Variation	Nil	Nil
No & Proceed		
Expected Outcome	Activity Uncompleted	Activity Uncompleted
Actual Outcome	Activity Uncompleted	Activity Uncompleted
Variation	Nil	Nil
Choose 'Continue' in Activity uncompleted		
Expected Outcome	Activity 26	Choose either activity 27 or 28
Actual Outcome	Activity 26	Choose either activity 27 or 28
Variation	Nil	Nil
Choose 'Not continue' in Activity uncompleted		
Expected Outcome	Report	Report
Actual Outcome	Report	Report
Variation	Nil	Nil
Processing		
Expected Outcome	Activity 26	Choose either activity 27 or 28
Actual Outcome	Activity 26	Choose either activity 27 or 28
Variation	Nil	Nil
Back		
Expected Outcome	Interim report 6	Activity 25
Actual Outcome	Interim report 6	Activity 25
Variation	Nil	Nil
Information		
Expected Outcome	Activity 25 (Information)	Activity 26 (Information)
Actual Outcome	Activity 25 (Information)	Activity 26 (Information)
Variation	Nil	Nil
Exit		
Actual Outcome	Report	Report
Expected Outcome	Report	Report
Variation	Nil	Nil

Choose either activity 27 or 28

Choose 27	
Actual outcome	Go to activity 27
Expected Outcome	Go to activity 27
Variation	Nil
Choose 28	
Actual outcome	Go to activity 28
Expected Outcome	Go to activity 28
Variation	Nil

	Activity 27	Activity 28		
Yes & Proceed				
Expected Outcome	Interim report 7 (see next page for further detail)	Interim report 7 (see next page for further detail)		
Actual Outcome	Interim report 7 (see next page for further detail)	Interim report 7 (see next page for further detail)		
Variation	Nil	Nil		
No & Proceed				
Expected Outcome	Activity Uncompleted	Activity Uncompleted		
Actual Outcome	Activity Uncompleted	Activity Uncompleted		
Variation	Nil	Nil		
Choose 'Continue' in Activity uncompleted				
Expected Outcome	Interim report 7 (see next page for further detail)	Interim report 7 (see next page for further detail)		
Actual Outcome	Interim report 7 (see next page for further detail)	Interim report 7 (see next page for further detail)		
Variation	Nil	Nil		
Choose 'Not continue' in Activity uncompleted				
Expected Outcome	Report	Report		
Actual Outcome	Report	Report		
Variation	Nil	Nil		
Processing				
Expected Outcome	Interim report 7 (see next page for further detail)	Interim report 7 (see next page for further detail)		
Actual Outcome	Interim report 7 (see next page for further detail)	Interim report 7 (see next page for further detail)		
Variation	Nil	Nil		
Back				
Expected Outcome	Choose either activity 27 or 28	Choose either activity 27 or 28		
Actual Outcome	Choose either activity 27 or 28	Choose either activity 27 or 28		
Variation	Nil	Nil		
Information				
Expected Outcome	Activity 27	Activity 28		
Actual Outcome	Activity 27	Activity 28		
Variation	Nil	Nil		
Exit				
Actual Outcome	Report	Report		
Expected Outcome	Report	Report		
Variation	Nil	Nil		

If the user finish all activities in section 6, then it will go to interim report 7.1.

Expected Outcome	Go to interim report 7.1
Actual Outcome	Go to interim report 7.1
Variation	Nil

If the user does not finish all activities in section 7, then it will go to interim report 7.2.

Expected Outcome	Go to interim report 7.2
Actual Outcome	Go to interim report 7.2
Variation	Nil

In either case, the user press 'OK', then it will go to 'Report'.

Expected Outcome	Report
Actual Outcome	Report
Variation	Nil

In either case, the user press 'Print', then it will print the report.

Expected Outcome	Print
Actual Outcome	Print
Variation	Nil

If the user choose activity 27 previously, it will go back to activity 27 if they press 'Back'.

Expected Outcome	Go to activity 27
Actual Outcome	Go to activity 27
Variation	Nil

If the user choose activity 28 previously, it will go back to activity 28 if they press 'Back'.

Expected Outcome	Go to activity 28
Actual Outcome	Go to activity 28
Variation	Nil

If the user press OK in 'Report' Screen, then it should go to Final Report section. There are different version final reports.

If the user finish all activities in this stage, then it will go to 'Related report' screen.

Expected Outcome	Go to Related report screen
Actual Outcome	Go to Related report screen
Variation	Nil

If the user press 'OK' at the 'Related report' screen, then it will go to Final Report.

Expected Outcome	Go to Final Report
Actual Outcome	Go to Final Report
Variation	Nil

At the Final Report screen

If the user press 'OK', then it will go to the End.

Expected Outcome	Go to End
Actual Outcome	Go to End
Variation	Nil

If the user press 'Back', then it will go back to 'Related report' screen.

Expected Outcome	Go to 'Related report' screen
Actual Outcome	Go to 'Related report' screen
Variation	Nil

If the user press 'Print', then it will print the report.

Expected Outcome	Print
Actual Outcome	Print
Variation	Nil

If the user does not finish activity 1 only, then it will go to 'Related reports' screen.

Expected Outcome	Go to 'Related reports' screen
Actual Outcome	Go to 'Related reports' screen
Variation	Nil

If the user press 'OK' at the 'Related reports' screen, then it will go to Final Report 1 (ignore Project Manager).

Expected Outcome	Go to Final Report 1 (ignore Project Manager)
Actual Outcome	Go to Final Report 1 (ignore Project Manager)
Variation	Nil

At the Final Report 1 (ignore Project Manager) screen

If the user press 'Further Information', then it will go to screen *Information for success factor 'Project Manager'*.

Expected Outcome	Information for success factor 'Project Manager'
Actual Outcome	Information for success factor 'Project Manager'
Variation	Nil

If the user press 'OK', then it will go to the End.

Expected Outcome	Go to End
Actual Outcome	Go to End
Variation	Nil

If the user press 'Back', then it will go back to 'Related reports' screen.

Expected Outcome	Go to 'Related reports' screen
Actual Outcome	Go to 'Related reports' screen
Variation	Nil

If the user press 'Print', then it will print the report.

Expected Outcome	Print
Actual Outcome	Print
Variation	Nil

If the user does not finish activity 2 only, then it will go to 'Related reports' screen.

Expected Outcome	Go to 'Related reports' screen
Actual Outcome	Go to 'Related reports' screen
Variation	Nil

If the user press 'OK' at the 'Related reports' screen, then it will go to Final Report 2.1 (ignore Scope of Project 1).

Expected Outcome	Go to Final Report 2.1 (ignore Scope of Project 1)
Actual Outcome	Go to Final Report 2.1 (ignore Scope of Project 1)
Variation	Nil

At the Final Report 2.1 (ignore Scope of project 1) screen

If the user press 'Further Information', then it will go to the screen *Information for success factor 'Scope of Project'*.

Expected Outcome	Information for success factor 'Scope of Project'
Actual Outcome	Information for success factor 'Scope of Project'
Variation	Nil

If the user press 'OK', then it will go to the End.

Expected Outcome	Go to End
Actual Outcome	Go to End
Variation	Nil

If the user press 'Back', then it will go back to 'Related reports' screen.

Expected Outcome	Go to 'Related reports' screen
Actual Outcome	Go to 'Related reports' screen
Variation	Nil

If the user press 'Print', then it will print the report.

Expected Outcome	Print
Actual Outcome	Print
Variation	Nil

If the user does not finish activity 2 and 11, then it will go to 'Related reports' screen.

Expected Outcome	Go to 'Related reports' screen
Actual Outcome	Go to 'Related reports' screen
Variation	Nil

If the user press 'OK' at the 'Related reports' screen, then it will go to Final Report 2.2 (ignore Scope of Project 2).

Expected Outcome	Go to Final Report 2.2 (ignore Scope of Project 2)
Actual Outcome	Go to Final Report 2.2 (ignore Scope of Project 2)
Variation	Nil

At the Final Report 2.2 (ignore Scope of Project 2) screen

If the user press 'Further Information', then it will go to *Information for success factor 'Scope of Project'*.

Expected Outcome	Information for success factor 'Scope of Project'
Actual Outcome	Information for success factor 'Scope of Project'
Variation	Nil

If the user press 'OK', then it will go to the End.

Expected Outcome	Go to End
Actual Outcome	Go to End
Variation	Nil

If the user press 'Back', then it will go back to 'Related reports' screen.

Expected Outcome	Go to 'Related reports' screen
Actual Outcome	Go to 'Related reports' screen
Variation	Nil

If the user press 'Print', then it will print the report.

Expected Outcome	Print
Actual Outcome	Print
Variation	Nil

If the user does not finish activity 3 only, then it will go to 'Related reports' screen.

Expected Outcome	Go to 'Related reports' screen
Actual Outcome	Go to 'Related reports' screen
Variation	Nil

If the user press 'OK' at the 'Related reports' screen, then it will go to Final Report 3 (ignore Project Objective).

Expected Outcome	Go to Final Report 3 (ignore Project Objective)
Actual Outcome	Go to Final Report3 (ignore Project Objective)
Variation	Nil

At the Final Report 3 (ignore Project Objective) screen

If the user press 'Further Information', then it will go to the screen *Information for success factor 'Project Objective'*.

Expected Outcome	Information for success factor 'Project Objective'
Actual Outcome	Information for success factor 'Project Objective'
Variation	Nil

If the user press 'OK', then it will go to the End.

Expected Outcome	Go to End
Actual Outcome	Go to End
Variation	Nil

If the user press 'Back', then it will go back to 'Related reports' screen.

Expected Outcome	Go to 'Related reports' screen
Actual Outcome	Go to 'Related reports' screen
Variation	Nil

If the user press 'Print', then it will print the report.

Expected Outcome	Print
Actual Outcome	Print
Variation	Nil

If the user does not finish activity 4 only, then it will go to 'Related reports' screen.

Expected Outcome	Go to 'Related reports' screen
Actual Outcome	Go to 'Related reports' screen
Variation	Nil

If the user press 'OK' at the 'Related reports' screen, then it will go to Final Report 4 (ignore Project Team).

Expected Outcome	Go to Final Report 4 (ignore Project Team)
Actual Outcome	Go to Final Report 4 (ignore Project Team)
Variation	Nil

At the Final Report (ignore project team) screen

If the user press 'Further Information', then it will go to Final Report (2nd Level).

Expected Outcome	Final Report (2nd Level)
Actual Outcome	Final Report (2nd Level)
Variation	Nil

If the user press 'OK', then it will go to the End.

Expected Outcome	Go to End
Actual Outcome	Go to End
Variation	Nil

If the user press 'Back', then it will go back to 'Related reports' screen.

Expected Outcome	Go to 'Related reports' screen
Actual Outcome	Go to 'Related reports' screen
Variation	Nil

If the user press 'Print', then it will print the report.

Expected Outcome	Print
Actual Outcome	Print
Variation	Nil

If the user does not finish activity 12 only, then it will go to 'Related reports' screen.

Expected Outcome	Go to 'Related reports' screen
Actual Outcome	Go to 'Related reports' screen
Variation	Nil

If the user press 'OK' at the 'Related reports' screen, then it will go to Final Report 5 (ignore Communication and Information Management).

Expected Outcome	Go to Final Report 5 (ignore Communication and Information Management)
Actual Outcome	Go to Final Report 5 (ignore Communication and Information Management)
Variation	Nil

At the Final Report 5 (ignore Communication and Information Management) screen

If the user press 'Further Information', then it will go to the screen *Information for success factor 'Communication and Information Management'*.

Expected Outcome	Information for success factor 'Communication and Information Management'
Actual Outcome	Information for success factor 'Communication and Information Management'
Variation	Nil

If the user press 'OK', then it will go to the End.

Expected Outcome	Go to End
Actual Outcome	Go to End
Variation	Nil

If the user press 'Back', then it will go back to 'Related reports' screen.

Expected Outcome	Go to 'Related reports' screen
Actual Outcome	Go to 'Related reports' screen
Variation	Nil

If the user press 'Print', then it will print the report.

Expected Outcome	Print
Actual Outcome	Print
Variation	Nil

If the user does not finish activity 14 only, then it will go to 'Related reports' screen.

Expected Outcome	Go to 'Related reports' screen
Actual Outcome	Go to 'Related reports' screen
Variation	Nil

If the user press 'OK' at the 'Related reports' screen, then it will go to Final Report 6 (ignore control).

Expected Outcome	Go to Final Report 6 (ignore control)
Actual Outcome	Go to Final Report 6 (ignore control)
Variation	Nil

At the Final Report 6 (ignore control) screen

If the user press 'Further Information', then it will go to the screen *Information for success factor 'Control'*.

Expected Outcome	Information for success factor 'Control'
Actual Outcome	Information for success factor 'Control'
Variation	Nil

If the user press 'OK', then it will go to the End.

Expected Outcome	Go to End
Actual Outcome	Go to End
Variation	Nil

If the user press 'Back', then it will go back to 'Related reports' screen.

Expected Outcome	Go to 'Related reports' screen
Actual Outcome	Go to 'Related reports' screen
Variation	Nil

If the user press 'Print', then it will print the report.

Expected Outcome	Print
Actual Outcome	Print
Variation	Nil

If the user does not finish activity 19 only, then it will go to 'Related reports' screen.

Expected Outcome	Go to 'Related reports' screen
Actual Outcome	Go to 'Related reports' screen
Variation	Nil

If the user press 'OK' at the 'Related reports' screen, then it will go to Final Report 7 (Health and Safety).

Expected Outcome	Go to Final Report 7 (Health and Safety)
Actual Outcome	Go to Final Report 7 (Health and Safety)
Variation	Nil

At the Final Report 7 (Health and Safety) screen

If the user press 'Further Information', then it will go to the screen *Information for success factor 'Health and Safety'*.

Expected Outcome	Information for success factor 'Health and Safety'
Actual Outcome	Information for success factor 'Health and Safety''
Variation	Nil

If the user press 'OK', then it will go to the End.

Expected Outcome	Go to End
Actual Outcome	Go to End
Variation	Nil

If the user press 'Back', then it will go back to 'Related reports' screen.

Expected Outcome	Go to 'Related reports' screen
Actual Outcome	Go to 'Related reports' screen
Variation	Nil

If the user press 'Print', then it will print the report.

Expected Outcome	Print
Actual Outcome	Print
Variation	Nil

Appendix 16

Verification checklist of file 'A_All'

A-All

A-All	
Proceed	
Expected Outcome	Go to dialogue box 'New Project'
Actual Outcome	Go to dialogue box 'New Project'
Variation	Nil

New Project	
Yes	
Expected Outcome	Open Projects from 'C:\ My Document \ Study \ .txt'
Actual Outcome	Open Projects from 'C:\ My Document \ Study \ .txt'
Variation	Nil
No	
Expected Outcome	Go to dialogue box 'Enter Project Number'
Actual Outcome	Go to dialogue box 'Enter Project Number'
Variation	Nil

Enter Project Number	
Enter Project Number & Proceed	
Expected Outcome	Go to dialogue box 'Participant'
Actual Outcome	Go to dialogue box 'Participant'
Variation	Nil

Participants	
Project Manager	
Expected Outcome	Go to dialogue box 'Activities'
Actual Outcome	Go to dialogue box 'Activities'
Variation	Nil
Architect	
Expected Outcome	Go to dialogue box 'Activities'
Actual Outcome	Go to dialogue box 'Activities'
Variation	Nil
Quantity Surveyor	
Expected Outcome	Go to dialogue box 'Activities'
Actual Outcome	Go to dialogue box 'Activities'
Variation	Nil
Structural Engineer	
Expected Outcome	Go to dialogue box 'Activities'
Actual Outcome	Go to dialogue box 'Activities'
Variation	Nil
Service Engineer	
Expected Outcome	Go to dialogue box 'Activities'
Actual Outcome	Go to dialogue box 'Activities'
Variation	Nil
Planning Supervisor	
Expected Outcome	Go to dialogue box 'Activities'
Actual Outcome	Go to dialogue box 'Activities'
Variation	Nil
Client	
Expected Outcome	Go to dialogue box 'Activities'
Actual Outcome	Go to dialogue box 'Activities'
Variation	Nil

If participant is Project Manager

	Activity 1	Activity 2	Activity 3	Activity 4
Yes & Proceed				
Expected Outcome	Activity 2	Activity 3	Activity 4	Interim report 1 (see next page for further detail)
Actual Outcome	Activity 2	Activity 3	Activity 4	Interim report 1 (see next page for further detail)
Variation	Nil	Nil	Nil	Nil
No & Proceed				
Expected Outcome	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted
Actual Outcome	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted
Variation	Nil	Nil	Nil	Nil
Choose 'Continue' in Activity uncompleted				
Expected Outcome	Activity 2	Activity 3	Activity 4	Interim report 1 (see next page for further detail)
Actual Outcome	Activity 2	Activity 3	Activity 4	Interim report 1 (see next page for further detail)
Variation	Nil	Nil	Nil	Nil
Choose 'Not continue' in Activity uncompleted				
Expected Outcome	Report	Report	Report	Report
Actual Outcome	Report	Report	Report	Report
Variation	Nil	Nil	Nil	Nil
Back				
Expected Outcome	A_All	Activity 1	Activity 2	Activity 3
Actual Outcome	A_All	Activity 1	Activity 2	Activity 3
Variation	Nil	Nil	Nil	Nil
Information				
Expected Outcome	Activity 1 (Information)	Activity 2 (Information)	Activity 3 (Information)	Activity 4 (Information)
Actual Outcome	Activity1 (Information)	Activity 2 (Information)	Activity 3 (Information)	Activity 4 (Information)
Variation	Nil	Nil	Nil	Nil
Exit				
Actual Outcome	Report	Report	Report	Report
Expected Outcome	Report	Report	Report	Report
Variation	Nil	Nil	Nil	Nil

If the user finish all activities in section 1, it will go to interim report 1.1.

Expected Outcome	Go to interim report 1.1
Actual Outcome	Go to interim report 1.1
Variation	Nil

If the user does not finish all activities in section 1, then it will go to interim report 1.2.

Expected Outcome	Go to interim report 1.2
Actual Outcome	Go to interim report 1.2
Variation	Nil

In either case, the user press 'OK', then it will go to activity 5.

Expected Outcome	Go to activity 5
Actual Outcome	Go to activity 5
Variation	Nil

In either case, the user press 'Back', then it will go to activity 4.

Expected Outcome	Go to activity 4
Actual Outcome	Go to activity 4
Variation	Nil

In either case, the user press 'Print', then it will print the report.

Expected Outcome	Print
Actual Outcome	Print
Variation	Nil

At the Interim Report 1.2 screen

If the user finish choose the first 'Information' icon, all activities in section 1, then it will go to screen *Information for success factor 'Project Manager'*.

Expected Outcome	Information for success factor 'Project Manager'
Actual Outcome	Information for success factor 'Project Manager'
Variation	Nil

If the user finish choose the second 'Information' icon, then it will go to screen *Information for success factor 'Scope of Project'*.

Expected Outcome	Information for success factor 'Scope of Project'
Actual Outcome	Information for success factor 'Scope of Project'
Variation	Nil

If the user finish choose the third 'Information' icon, then it will go to screen *Information for success factor 'Project Objective'*.

Expected Outcome	Information for success factor 'Project Objective'
Actual Outcome	Information for success factor 'Project Objective'
Variation	Nil

	Activity 5	Activity 6	Activity 6a	Activity 6b
Yes & Proceed				
Expected Outcome	Activity 6	Activity 6a	Activity 6b	Activity 6c
Actual Outcome	Activity 6	Activity 6a	Activity 6b	Activity 6c
Variation	Nil	Nil	Nil	Nil
No & Proceed				
Expected Outcome	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted
Actual Outcome	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted
Variation	Nil	Nil	Nil	Nil
Choose 'Continue' in Activity uncompleted				
Expected Outcome	Activity 6	Activity 6a	Activity 6b	Activity 6c
Actual Outcome	Activity 6	Activity 6a	Activity 6b	Activity 6c
Variation	Nil	Nil	Nil	Nil
Choose 'Not continue' in Activity uncompleted				
Expected Outcome	Report	Report	Report	Report
Actual Outcome	Report	Report	Report	Report
Variation	Nil	Nil	Nil	Nil
Back				
Expected Outcome	Interim report 1	Activity 5	Activity 6	Activity 6a
Actual Outcome	Interim report 1	Activity 5	Activity 6	Activity 6a
Variation	Nil	Nil	Nil	Nil
Information				
Expected Outcome	Activity 5 (Information)	Activity 6 (Information)	Activity 6a (Information)	Activity 6b (Information)
Actual Outcome	Activity 5 (Information)	Activity 6 (Information)	Activity 6a (Information)	Activity 6b (Information)
Variation	Nil	Nil	Nil	Nil
Exit				
Actual Outcome	Report	Report	Report	Report
Expected Outcome	Report	Report	Report	Report
Variation	Nil	Nil	Nil	Nil

	Activity 6c	Activity 6d	Activity 7	Activity 8
Yes & Proceed				
Expected Outcome	Activity 6d	Activity 7	Activity 8	Interim report 2 (see next page for further detail)
Actual Outcome	Activity 6d	Activity 7	Activity 8	Interim report 2 (see next page for further detail)
Variation	Nil	Nil	Nil	Nil
No & Proceed				
Expected Outcome	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted
Actual Outcome	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted
Variation	Nil	Nil	Nil	Nil
Choose 'Continue' in Activity uncompleted				
Expected Outcome	Activity 6d	Activity 7	Activity 8	Interim report 2 (see next page for further detail)
Actual Outcome	Activity 6d	Activity 7	Activity 8	Interim report 2 (see next page for further detail)
Variation	Nil	Nil	Nil	Nil
Choose 'Not continue' in Activity uncompleted				
Expected Outcome	Report	Report	Report	Report
Actual Outcome	Report	Report	Report	Report
Variation	Nil	Nil	Nil	Nil
Back				
Expected Outcome	Activity 6b	Activity 6c	Activity 6d	Activity 7
Actual Outcome	Activity 6b	Activity 6c	Activity 6d	Activity 7
Variation	Nil	Nil	Nil	Nil
Information				
Expected Outcome	Activity 6c (Information)	Activity 6d (Information)	Activity 7 (Information)	Activity 8 (Information)
Actual Outcome	Activity 6c (Information)	Activity 6d (Information)	Activity 7 (Information)	Activity 8 (Information)
Variation	Nil	Nil	Nil	Nil
Exit				
Actual Outcome	Report	Report	Report	Report
Expected Outcome	Report	Report	Report	Report
Variation	Nil	Nil	Nil	Nil

If the user finish all activities in section 2, then it will go to interim report 2.1.

Expected Outcome	Go to interim report 2.1
Actual Outcome	Go to interim report 2.1
Variation	Nil

If the user does not finish all activities in section 2, then it will go to interim report 2.2.

Expected Outcome	Go to interim report 2.2
Actual Outcome	Go to interim report 2.2
Variation	Nil

In either case, the user press 'OK', then it will go to activity 9.

Expected Outcome	Go to activity 9
Actual Outcome	Go to activity 9
Variation	Nil

In either case, the user press 'Back', then it will go to activity 8.

Expected Outcome	Go to activity 8
Actual Outcome	Go to activity 8
Variation	Nil

In either case, the user press 'Print', then it will print the report.

Expected Outcome	Print
Actual Outcome	Print
Variation	Nil

At the Interim Report 2.2 screen

If the user finish choose the 'Information' icon, all activities in section 1, then it will go to screen *Information for success factor 'Project Team'*.

Expected Outcome	Information for success factor 'Project Team'
Actual Outcome	Information for success factor 'Project Team'
Variation	Nil

	Activity 9	Activity 10	Activity 11	Activity 12
Yes & Proceed				
Expected Outcome	Activity 10	Activity 11	Activity 12	Interim report 3 (see next page for further detail)
Actual Outcome	Activity 10	Activity 11	Activity 12	Interim report 3 (see next page for further detail)
Variation	Nil	Nil	Nil	Nil
No & Proceed				
Expected Outcome	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted
Actual Outcome	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted
Variation	Nil	Nil	Nil	Nil
Choose 'Continue' in Activity uncompleted				
Expected Outcome	Activity 10	Activity 11	Activity 12	Interim report 3 (see next page for further detail)
Actual Outcome	Activity 10	Activity 11	Activity 12	Interim report 3 (see next page for further detail)
Variation	Nil	Nil	Nil	Nil
Choose 'Not continue' in Activity uncompleted				
Expected Outcome	Report	Report	Report	Report
Actual Outcome	Report	Report	Report	Report
Variation	Nil	Nil	Nil	Nil
Back				
Expected Outcome	Interim report 2	Activity 9	Activity 10	Activity 11
Actual Outcome	Interim report 2	Activity 9	Activity 10	Activity 11
Variation	Nil	Nil	Nil	Nil
Information				
Expected Outcome	Activity 9 (Information)	Activity 10 (Information)	Activity 11 (Information)	Activity 12 (Information)
Actual Outcome	Activity 9 (Information)	Activity 10 (Information)	Activity 11 (Information)	Activity 12 (Information)
Variation	Nil	Nil	Nil	Nil
Exit				
Actual Outcome	Report	Report	Report	Report
Expected Outcome	Report	Report	Report	Report
Variation	Nil	Nil	Nil	Nil

If the user finish all activities in section 3, then it will go to interim report 3.1.

Expected Outcome	Go to interim report 3.1
Actual Outcome	Go to interim report 3.1
Variation	Nil

If the user does not finish all activities in section 3, then it will go to interim report 3.2.

Expected Outcome	Go to interim report 3.2
Actual Outcome	Go to interim report 3.2
Variation	Nil

In either case, the user press 'OK', then it will go to activity 13.

Expected Outcome	Go to activity 13
Actual Outcome	Go to activity 13
Variation	Nil

In either case, the user press 'Back', then it will go to activity 12.

Expected Outcome	Go to activity 12
Actual Outcome	Go to activity 12
Variation	Nil

In either case, the user press 'Print', then it will print the report.

Expected Outcome	Print
Actual Outcome	Print
Variation	Nil

At the Interim Report 3.2 screen

If the user finish choose the first 'Information' icon, all activities in section 1, then it will go to screen *Information for success factor 'Scope of Project'.*

Expected Outcome	Information for success factor 'Scope of Project'
Actual Outcome	Information for success factor 'Scope of Project'
Variation	Nil

If the user finish choose the second 'Information' icon, then it will go to screen *Information for success factor 'Communication and Information Management'.*

Expected Outcome	Information for success factor 'Communication and Information Management'
Actual Outcome	Information for success factor ''Communication and Information Management'
Variation	Nil

	Activity 13	Activity 13a	Activity 14	Activity 14a
Yes & Proceed				
Expected Outcome	Activity 13a	Activity 14	Activity 14a	Activity 14b
Actual Outcome	Activity 13a	Activity 14	Activity 14a	Activity 14b
Variation	Nil	Nil	Nil	Nil
No & Proceed				
Expected Outcome	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted
Actual Outcome	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted
Variation	Nil	Nil	Nil	Nil
Choose 'Continue' in Activity uncompleted				
Expected Outcome	Activity 13a	Activity 14	Activity 14a	Activity 14b
Actual Outcome	Activity 13a	Activity 14	Activity 14a	Activity 14b
Variation	Nil	Nil	Nil	Nil
Choose 'Not continue' in Activity uncompleted				
Expected Outcome	Report	Report	Report	Report
Actual Outcome	Report	Report	Report	Report
Variation	Nil	Nil	Nil	Nil
Back				
Expected Outcome	Interim report 3	Activity 13	Activity 13a	Activity 14
Actual Outcome	Interim report 3	Activity 13	Activity 13a	Activity 14
Variation	Nil	Nil	Nil	Nil
Information				
Expected Outcome	Activity 13 (Information)	Activity 13a (Information)	Activity 14 (Information)	Activity 14a (Information)
Actual Outcome	Activity 13 (Information)	Activity 13a (Information)	Activity 14 (Information)	Activity 14a (Information)
Variation	Nil	Nil	Nil	Nil
Exit				
Actual Outcome	Report	Report	Report	Report
Expected Outcome	Report	Report	Report	Report
Variation	Nil	Nil	Nil	Nil

	Activity 14b	Activity 14c	Activity 14d	Activity 14e
Yes & Proceed				
Expected Outcome	Activity 14c	Activity 14d	Activity 14e	Activity 14f
Actual Outcome	Activity 14c	Activity 14d	Activity 14e	Activity 14f
Variation	Nil	Nil	Nil	Nil
No & Proceed				
Expected Outcome	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted
Actual Outcome	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted
Variation	Nil	Nil	Nil	Nil
Choose 'Continue' in Activity uncompleted				
Expected Outcome	Activity 14c	Activity 14d	Activity 14e	Activity 14f
Actual Outcome	Activity 14c	Activity 14d	Activity 14e	Activity 14f
Variation	Nil	Nil	Nil	Nil
Choose 'Not continue' in Activity uncompleted				
Expected Outcome	Report	Report	Report	Report
Actual Outcome	Report	Report	Report	Report
Variation	Nil	Nil	Nil	Nil
Back				
Expected Outcome	Activity 14a	Activity 14b	Activity 14c	Activity 14d
Actual Outcome	Activity 14a	Activity 14b	Activity 14c	Activity 14d
Variation	Nil	Nil	Nil	Nil
Information				
Expected Outcome	Activity 14b (Information)	Activity 14c (Information)	Activity 14d (Information)	Activity 14e (Information)
Actual Outcome	Activity 14b (Information)	Activity 14c (Information)	Activity 14d (Information)	Activity 14d (Information)
Variation	Nil	Nil	Nil	Nil
Exit				
Actual Outcome	Report	Report	Report	Report
Expected Outcome	Report	Report	Report	Report
Variation	Nil	Nil	Nil	Nil

	Activity 14f	Activity 14g	Activity 14h	Activity 15
Yes & Proceed				
Expected Outcome	Activity 14g	Activity 14h	Activity 15	Activity 15a
Actual Outcome	Activity 14g	Activity 14h	Activity 15	Activity 15a
Variation	Nil	Nil	Nil	Nil
No & Proceed				
Expected Outcome	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted
Actual Outcome	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted
Variation	Nil	Nil	Nil	Nil
Choose 'Continue' in Activity uncompleted				
Expected Outcome	Activity 14g	Activity 14h	Activity 15	Activity 15a
Actual Outcome	Activity 14g	Activity 14h	Activity 15	Activity 15a
Variation	Nil	Nil	Nil	Nil
Choose 'Not continue' in Activity uncompleted				
Expected Outcome	Report	Report	Report	Report
Actual Outcome	Report	Report	Report	Report
Variation	Nil	Nil	Nil	Nil
Back				
Expected Outcome	Activity14e	Activity 14f	Activity 14g	Activity 14h
Actual Outcome	Activity14e	Activity 14f	Activity 14g	Activity 14h
Variation	Nil	Nil	Nil	Nil
Information				
Expected Outcome	Activity 14f (Information)	Activity 14g (Information)	Activity 14h (Information)	Activity 15 (Information)
Actual Outcome	Activity 14f (Information)	Activity 14g (Information)	Activity 14h (Information)	Activity 15 (Information)
Variation	Nil	Nil	Nil	Nil
Exit				
Actual Outcome	Report	Report	Report	Report
Expected Outcome	Report	Report	Report	Report
Variation	Nil	Nil	Nil	Nil

	Activity 15a	Activity 16		
Yes & Proceed				
Expected Outcome	Activity 16	Interim report 4 (see next page for further detail)		
Actual Outcome	Activity 16	Interim report 4 (see next page for further detail)		
Variation	Nil	Nil		
No & Proceed				
Expected Outcome	Activity Uncompleted	Activity Uncompleted		
Actual Outcome	Activity Uncompleted	Activity Uncompleted		
Variation	Nil	Nil		
Choose 'Continue' in Activity uncompleted				
Expected Outcome	Activity 16	Interim report 4 (see next page for further detail)		
Actual Outcome	Activity 16	Interim report 4 (see next page for further detail)		
Variation	Nil	Nil		
Choose 'Not continue' in Activity uncompleted				
Expected Outcome	Report	Report		
Actual Outcome	Report	Report		
Variation	Nil	Nil		
Back				
Expected Outcome	Activity 15	Activity 15a		
Actual Outcome	Activity 15	Activity 15a		
Variation	Nil	Nil		
Information				
Expected Outcome	Activity 15a (Information)	Activity 16 (Information)		
Actual Outcome	Activity 15a (Information)	Activity 16 (Information)		
Variation	Nil	Nil		
Exit				
Actual Outcome	Report	Report		
Expected Outcome	Report	Report		
Variation	Nil	Nil		

If the user finish all activities in section 4a then it will go to interim report 4.1.

Expected Outcome	Go to interim report 4.1
Actual Outcome	Go to interim report 4.1
Variation	Nil

If the user does not finish all activities in section 4a, then it will go to interim report 4.2.

Expected Outcome	Go to interim report 4.2
Actual Outcome	Go to interim report a.2
Variation	Nil

In either case, the user press 'OK', then it will go to activity 17.

Expected Outcome	Go to activity 17
Actual Outcome	Go to activity 17
Variation	Nil

In either case, the user press 'Back', then it will go to activity 12.

Expected Outcome	Go to activity 12
Actual Outcome	Go to activity 12
Variation	Nil

In either case, the user press 'Print', then it will print the report.

Expected Outcome	Print
Actual Outcome	Print
Variation	Nil

At the Interim Report 4.2 screen

If the user finish choose the first 'Information' icon, all activities in section 1, then it will go to screen *Information for success factor 'Control'*.

Expected Outcome	Information for success factor 'Control'
Actual Outcome	Information for success factor 'Control'
Variation	Nil

	Activity 18	Activity 19	Activity 20	Activity 20a
Yes & Proceed				
Expected Outcome	Activity 19	Activity 20	Activity 20a	Activity 20b
Actual Outcome	Activity 19	Activity 20	Activity 20a	Activity 20b
Variation	Nil	Nil	Nil	Nil
No & Proceed				
Expected Outcome	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted
Actual Outcome	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted
Variation	Nil	Nil	Nil	Nil
Choose 'Continue' in Activity uncompleted				
Expected Outcome	Activity 19	Activity 20	Activity 20a	Activity 20b
Actual Outcome	Activity 19	Activity 20	Activity 20a	Activity 20b
Variation	Nil	Nil	Nil	Nil
Choose 'Not continue' in Activity uncompleted				
Expected Outcome	Report	Report	Report	Report
Actual Outcome	Report	Report	Report	Report
Variation	Nil	Nil	Nil	Nil
Back				
Expected Outcome	Interim report 4	Activity 18	Activity 19	Activity 20
Actual Outcome	Interim report 4	Activity 18	Activity 19	Activity 20
Variation	Nil	Nil	Nil	Nil
Information				
Expected Outcome	Activity 18 (Information)	Activity 19 (Information)	Activity 20 (Information)	Activity 20a (Information)
Actual Outcome	Activity 18 (Information)	Activity 19 (Information)	Activity 20 (Information)	Activity 20a (Information)
Variation	Nil	Nil	Nil	Nil
Exit				
Actual Outcome	Report	Report	Report	Report
Expected Outcome	Report	Report	Report	Report
Variation	Nil	Nil	Nil	Nil

	Activity 20b	Activity 20c		
Yes & Proceed				
Expected Outcome	Activity 20c	Interim report 5 (see next page for further detail)		
Actual Outcome	Activity 20c	Interim report 5 (see next page for further detail)		
Variation	Nil	Nil		
No & Proceed				
Expected Outcome	Activity Uncompleted	Activity Uncompleted		
Actual Outcome	Activity Uncompleted	Activity Uncompleted		
Variation	Nil	Nil		
Choose 'Continue' in Activity uncompleted				
Expected Outcome	Activity 20c	Interim report 5 (see next page for further detail)		
Actual Outcome	Activity 20c	Interim report 5 (see next page for further detail)		
Variation	Nil	Nil		
Choose 'Not continue' in Activity uncompleted				
Expected Outcome	Report	Report		
Actual Outcome	Report	Report		
Variation	Nil	Nil		
Back				
Expected Outcome	Activity 20a	Activity 20b		
Actual Outcome	Activity 20a	Activity 20b		
Variation	Nil	Nil		
Information				
Expected Outcome	Activity 20b (Information)	Activity 20c (Information)		
Actual Outcome	Activity 20b (Information)	Activity 20c (Information)		
Variation	Nil	Nil		
Exit				
Actual Outcome	Report	Report		
Expected Outcome	Report	Report		
Variation	Nil	Nil		

If the user finish all activities in section 5, then it will go to interim report 5.1.

Expected Outcome	Go to interim report 5.1
Actual Outcome	Go to interim report 5.1
Variation	Nil

If the user does not finish all activities in section 5, then it will go to interim report 5.2.

Expected Outcome	Go to interim report 5.2
Actual Outcome	Go to interim report 5.2
Variation	Nil

In either case, the user press 'OK', then it will go to activity 21.

Expected Outcome	Go to activity 21
Actual Outcome	Go to activity 21
Variation	Nil

In either case, the user press 'back', then it will go to activity 20d.

Expected Outcome	Go to activity 20d
Actual Outcome	Go to activity 20d
Variation	Nil

In either case, the user press 'Print', then it will print the report.

Expected Outcome	Print
Actual Outcome	Print
Variation	Nil

At the Interim Report 5.2 screen

If the user finish choose the 'Information' icon, all activities in section 1, then it will go to screen *Information for success factor 'Health and Safety'*.

Expected Outcome	Information for success factor 'Health and Safety'
Actual Outcome	Information for success factor 'Health and Safety'
Variation	Nil

	Activity 21	Activity 22	Activity 23
Yes & Proceed			
Expected Outcome	Activity 22	Activity 23	Interim report 6 (see next page for further detail)
Actual Outcome	Activity 22	Activity 23	Interim report 6 (see next page for further detail)
Variation	Nil	Nil	Nil
No & Proceed			
Expected Outcome	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted
Actual Outcome	Activity Uncompleted	Activity Uncompleted	Activity Uncompleted
Variation	Nil	Nil	Nil
Choose 'Continue' in Activity uncompleted			
Expected Outcome	Activity 22	Activity 23	Interim report 6 (see next page for further detail)
Actual Outcome	Activity 22	Activity 23	Interim report 6 (see next page for further detail)
Variation	Nil	Nil	Nil
Choose 'Not continue' in Activity uncompleted			
Expected Outcome	Report	Report	Report
Actual Outcome	Report	Report	Report
Variation	Nil	Nil	Nil
Back			
Expected Outcome	Interim report 5	Activity 21	Activity 22
Actual Outcome	Interim report 5	Activity 21	Activity 22
Variation	Nil	Nil	Nil
Information			
Expected Outcome	Activity 21 (Information)	Activity 22 (Information)	Activity 23 (Information)
Actual Outcome	Activity 21 (Information)	Activity 22 (Information)	Activity 23 (Information)
Variation	Nil	Nil	Nil
Exit			
Actual Outcome	Report	Report	Report
Expected Outcome	Report	Report	Report
Variation	Nil	Nil	Nil

If the user finish all activities in section 6, then it will go to interim report 6.1.

Expected Outcome	Go to interim report 6.1
Actual Outcome	Go to interim report 6.1
Variation	Nil

If the user does not finish all activities in section 6, then it will go to interim report 6.2.

Expected Outcome	Go to interim report 6.2
Actual Outcome	Go to interim report 6.2
Variation	Nil

In either case, the user press 'OK', then it will go to activity 25.

Expected Outcome	Go to activity 25
Actual Outcome	Go to activity 25
Variation	Nil

If the user choose activity 23 previously, it will go back to activity 23 if they press 'Back'.

Expected Outcome	Go to activity 23
Actual Outcome	Go to activity 23
Variation	Nil

If the user choose activity 24 previously, it will go back to activity 24 if they press 'Back'.

Expected Outcome	Go to activity 24
Actual Outcome	Go to activity 24
Variation	Nil

In either case, the user press 'Print', then it will print the report.

Expected Outcome	Print
Actual Outcome	Print
Variation	Nil

	Activity 27			
Yes & Proceed				
Expected Outcome	Interim report 7 see next page for further detail)			
Actual Outcome	Interim report 7 see next page for further detail)			
Variation	Nil			
No & Proceed				
Expected Outcome	Activity Uncompleted			
Actual Outcome	Activity Uncompleted			
Variation	Nil			
Choose 'Continue' in Activity uncompleted				
Expected Outcome	Interim report 7 see next page for further detail)			
Actual Outcome	Interim report 7 see next page for further detail)			
Variation	Nil			
Choose 'Not continue' in Activity uncompleted				
Expected Outcome	Report			
Actual Outcome	Report			
Variation	Nil			
Back				
Expected Outcome	Interim report 6			
Actual Outcome	Interim report 6			
Variation	Nil			
Information				
Expected Outcome	Activity 27 (Information)			
Actual Outcome	Activity 27 (Information)			
Variation	Nil			
Exit				
Actual Outcome	Report			
Expected Outcome	Report			
Variation	Nil			

If the user finish all activities in section 6, then it will go to interim report 7.1.

Expected Outcome	Go to interim report 7.1
Actual Outcome	Go to interim report 7.1
Variation	Nil

If the user does not finish all activities in section 7, then it will go to interim report 7.2.

Expected Outcome	Go to interim report 7.2
Actual Outcome	Go to interim report 7.2
Variation	Nil

In either case, the user press 'OK', then it will go to 'Report'.

Expected Outcome	Report
Actual Outcome	Report
Variation	Nil

In either case, the user press 'Print', then it will print the report.

Expected Outcome	Print
Actual Outcome	Print
Variation	Nil

If the user choose activity 27 previously, it will go back to activity 27 if they press 'Back'.

Expected Outcome	Go to activity 27
Actual Outcome	Go to activity 27
Variation	Nil

If the user choose activity 28 previously, it will go back to activity 28 if they press 'Back'.

Expected Outcome	Go to activity 28
Actual Outcome	Go to activity 28
Variation	Nil

If the user press OK in 'Report' Screen, then it should go to Final Report section. There are different version final reports.

If the user finish all activities in this stage, then it will go to 'Related report' screen.

Expected Outcome	Go to Related report screen
Actual Outcome	Go to Related report screen
Variation	Nil

If the user press 'OK' at the 'Related report' screen, then it will go to Final Report.

Expected Outcome	Go to Final Report
Actual Outcome	Go to Final Report
Variation	Nil

At the Final Report screen

If the user press 'OK', then it will go to the End.

Expected Outcome	Go to End
Actual Outcome	Go to End
Variation	Nil

If the user press 'Back', then it will go back to 'Related report' screen.

Expected Outcome	Go to 'Related report' screen
Actual Outcome	Go to 'Related report' screen
Variation	Nil

If the user press 'Print', then it will print the report.

Expected Outcome	Print
Actual Outcome	Print
Variation	Nil

If the user does not finish activity 1 only, then it will go to 'Related reports' screen.

Expected Outcome	Go to 'Related reports' screen
Actual Outcome	Go to 'Related reports' screen
Variation	Nil

If the user press 'OK' at the 'Related reports' screen, then it will go to Final Report 1 (ignore Project Manager).

Expected Outcome	Go to Final Report 1 (ignore Project Manager)
Actual Outcome	Go to Final Report 1 (ignore Project Manager)
Variation	Nil

At the Final Report 1 (ignore Project Manager) screen

If the user press 'Further Information', then it will go to screen *Information for success factor 'Project Manager'*.

Expected Outcome	Information for success factor 'Project Manager'
Actual Outcome	Information for success factor 'Project Manager'
Variation	Nil

If the user press 'OK', then it will go to the End.

Expected Outcome	Go to End
Actual Outcome	Go to End
Variation	Nil

If the user press 'Back', then it will go back to 'Related reports' screen.

Expected Outcome	Go to 'Related reports' screen
Actual Outcome	Go to 'Related reports' screen
Variation	Nil

If the user press 'Print', then it will print the report.

Expected Outcome	Print
Actual Outcome	Print
Variation	Nil

If the user does not finish activity 2 only, then it will go to 'Related reports' screen.

Expected Outcome	Go to 'Related reports' screen
Actual Outcome	Go to 'Related reports' screen
Variation	Nil

If the user press 'OK' at the 'Related reports' screen, then it will go to Final Report 2.1 (ignore Scope of Project 1).

Expected Outcome	Go to Final Report 2.1 (ignore Scope of Project 1)
Actual Outcome	Go to Final Report 2.1 (ignore Scope of Project 1)
Variation	Nil

At the Final Report 2.1 (ignore Scope of project 1) screen

If the user press 'Further Information', then it will go to the screen *Information for success factor 'Scope of Project'*.

Expected Outcome	Information for success factor 'Scope of Project'
Actual Outcome	Information for success factor 'Scope of Project'
Variation	Nil

If the user press 'OK', then it will go to the End.

Expected Outcome	Go to End
Actual Outcome	Go to End
Variation	Nil

If the user press 'Back', then it will go back to 'Related reports' screen.

Expected Outcome	Go to 'Related reports' screen
Actual Outcome	Go to 'Related reports' screen
Variation	Nil

If the user press 'Print', then it will print the report.

Expected Outcome	Print
Actual Outcome	Print
Variation	Nil

If the user does not finish activity 2 and 11, then it will go to 'Related reports' screen.

Expected Outcome	Go to 'Related reports' screen
Actual Outcome	Go to 'Related reports' screen
Variation	Nil

If the user press 'OK' at the 'Related reports' screen, then it will go to Final Report 2.2 (ignore Scope of Project 2).

Expected Outcome	Go to Final Report 2.2 (ignore Scope of Project 2)
Actual Outcome	Go to Final Report 2.2 (ignore Scope of Project 2)
Variation	Nil

At the Final Report 2.2 (ignore Scope of Project 2) screen

If the user press 'Further Information', then it will go to *Information for success factor 'Scope of Project'.*

Expected Outcome	Information for success factor 'Scope of Project'
Actual Outcome	Information for success factor 'Scope of Project'
Variation	Nil

If the user press 'OK', then it will go to the End.

Expected Outcome	Go to End
Actual Outcome	Go to End
Variation	Nil

If the user press 'Back', then it will go back to 'Related reports' screen.

Expected Outcome	Go to 'Related reports' screen
Actual Outcome	Go to 'Related reports' screen
Variation	Nil

If the user press 'Print', then it will print the report.

Expected Outcome	Print
Actual Outcome	Print
Variation	Nil

If the user does not finish activity 3 only, then it will go to 'Related reports' screen.

Expected Outcome	Go to 'Related reports' screen
Actual Outcome	Go to 'Related reports' screen
Variation	Nil

If the user press 'OK' at the 'Related reports' screen, then it will go to Final Report 3 (ignore Project Objective).

Expected Outcome	Go to Final Report 3 (ignore Project Objective)
Actual Outcome	Go to Final Report 3 (ignore Project Objective)
Variation	Nil

At the Final Report 3 (ignore Project Objective) screen

If the user press 'Further Information', then it will go to the screen *Information for success factor 'Project Objective'*.

Expected Outcome	Information for success factor 'Project Objective'
Actual Outcome	Information for success factor 'Project Objective'
Variation	Nil

If the user press 'OK', then it will go to the End.

Expected Outcome	Go to End
Actual Outcome	Go to End
Variation	Nil

If the user press 'Back', then it will go back to 'Related reports' screen.

Expected Outcome	Go to 'Related reports' screen
Actual Outcome	Go to 'Related reports' screen
Variation	Nil

If the user press 'Print', then it will print the report.

Expected Outcome	Print
Actual Outcome	Print
Variation	Nil

If the user does not finish activity4 only, then it will go to 'Related reports' screen.

Expected Outcome	Go to 'Related reports' screen
Actual Outcome	Go to 'Related reports' screen
Variation	Nil

If the user press 'OK' at the 'Related reports' screen, then it will go to Final Report 4 (ignore Project Team).

Expected Outcome	Go to Final Report 4 (ignore Project Team)
Actual Outcome	Go to Final Report 4 (ignore Project Team)
Variation	Nil

At the Final Report 4 (ignore project team) screen

If the user press 'Further Information', then it will go to Final Report (2nd Level).

Expected Outcome	Final Report (2nd Level)
Actual Outcome	Final Report (2nd Level)
Variation	Nil

If the user press 'OK', then it will go to the End.

Expected Outcome	Go to End
Actual Outcome	Go to End
Variation	Nil

If the user press 'Back', then it will go back to 'Related reports' screen.

Expected Outcome	Go to 'Related reports' screen
Actual Outcome	Go to 'Related reports' screen
Variation	Nil

If the user press 'Print', then it will print the report.

Expected Outcome	Print
Actual Outcome	Print
Variation	Nil

If the user does not finish activity 12 only, then it will go to 'Related reports' screen.

Expected Outcome	Go to 'Related reports' screen
Actual Outcome	Go to 'Related reports' screen
Variation	Nil

If the user press 'OK' at the 'Related reports' screen, then it will go to Final Report 5 (ignore Communication and Information Management).

Expected Outcome	Go to Final Report 5 (ignore Communication and Information Management)
Actual Outcome	Go to Final Report 5 (ignore Communication and Information Management)
Variation	Nil

At the Final Report 5 (ignore Communication and Information Management) screen

If the user press 'Further Information', then it will go to the screen *Information for success factor 'Communication and Information Management'*.

Expected Outcome	Information for success factor 'Communication and Information Management'
Actual Outcome	Information for success factor 'Communication and Information Management'
Variation	Nil

If the user press 'OK', then it will go to the End.

Expected Outcome	Go to End
Actual Outcome	Go to End
Variation	Nil

If the user press 'Back', then it will go back to 'Related reports' screen.

Expected Outcome	Go to 'Related reports' screen
Actual Outcome	Go to 'Related reports' screen
Variation	Nil

If the user press 'Print', then it will print the report.

Expected Outcome	Print
Actual Outcome	Print
Variation	Nil

If the user does not finish activity 14 only, then it will go to 'Related reports' screen.

Expected Outcome	Go to 'Related reports' screen
Actual Outcome	Go to 'Related reports' screen
Variation	Nil

If the user press 'OK' at the 'Related reports' screen, then it will go to Final Report 6 (ignore control).

Expected Outcome	Go to Final Report 6 (ignore control)
Actual Outcome	Go to Final Report 6 (ignore control)
Variation	Nil

At the Final Report 6 (ignore control) screen

If the user press 'Further Information', then it will go to the screen *Information for success factor 'Control'*.

Expected Outcome	Information for success factor 'Control'
Actual Outcome	Information for success factor 'Control'
Variation	Nil

If the user press 'OK', then it will go to the End.

Expected Outcome	Go to End
Actual Outcome	Go to End
Variation	Nil

If the user press 'Back', then it will go back to 'Related reports' screen.

Expected Outcome	Go to 'Related reports' screen
Actual Outcome	Go to 'Related reports' screen
Variation	Nil

If the user press 'Print', then it will print the report.

Expected Outcome	Print
Actual Outcome	Print
Variation	Nil

If the user does not finish activity 19 only, then it will go to 'Related reports' screen.

Expected Outcome	Go to 'Related reports' screen
Actual Outcome	Go to 'Related reports' screen
Variation	Nil

If the user press 'OK' at the 'Related reports' screen, then it will go to Final Report 7 (Health and Safety).

Expected Outcome	Go to Final Report 7 (Health and Safety)
Actual Outcome	Go to Final Report 7 (Health and Safety)
Variation	Nil

At the Final Report 7 (Health and Safety) screen

If the user press 'Further Information', then it will go to the screen *Information for success factor 'Health and Safety'.*

Expected Outcome	Information for success factor 'Health and Safety'
Actual Outcome	Information for success factor 'Health and Safety''
Variation	Nil

If the user press 'OK', then it will go to the End.

Expected Outcome	Go to End
Actual Outcome	Go to End
Variation	Nil

If the user press 'Back', then it will go back to 'Related reports' screen.

Expected Outcome	Go to 'Related reports' screen
Actual Outcome	Go to 'Related reports' screen
Variation	Nil

If the user press 'Print', then it will print the report.

Expected Outcome	Print
Actual Outcome	Print
Variation	Nil

The idea for doing micro-verification for other roles is same as 'project manager', so it will not shown in the appendix.

Appendix 17

Verification checklist of file 'A_Main'

A-Main

A-Main	
Proceed	
Expected Outcome	Go to dialogue box 'New Project'
Actual Outcome	Go to dialogue box 'New Project'
Variation	Nil

New Project	
Yes	
Expected Outcome	Open Projects from 'C:\ My Document \ Study \ .txt'
Actual Outcome	Open Projects from 'C:\ My Document \ Study \ .txt'
Variation	Nil
No	
Expected Outcome	Go to dialogue box 'Enter Project Number'
Actual Outcome	Go to dialogue box 'Enter Project Number'
Variation	Nil

Enter Project Number	
Enter Project Number & Proceed	
Expected Outcome	Go to dialogue box 'Participant'
Actual Outcome	Go to dialogue box 'Participant'
Variation	Nil

Participants	
Project Manager	
Expected Outcome	Go to dialogue box 'Activities'
Actual Outcome	Go to dialogue box 'Activities'
Variation	Nil
Architect	
Expected Outcome	Go to dialogue box 'Activities'
Actual Outcome	Go to dialogue box 'Activities'
Variation	Nil
Quantity Surveyor	
Expected Outcome	Go to dialogue box 'Activities'
Actual Outcome	Go to dialogue box 'Activities'
Variation	Nil
Structural Engineer	
Expected Outcome	Go to dialogue box 'Activities'
Actual Outcome	Go to dialogue box 'Activities'
Variation	Nil
Service Engineer	
Expected Outcome	Go to dialogue box 'Activities'
Actual Outcome	Go to dialogue box 'Activities'
Variation	Nil
Planning Supervisor	
Expected Outcome	Go to dialogue box 'Activities'
Actual Outcome	Go to dialogue box 'Activities'
Variation	Nil
Client	
Expected Outcome	Go to dialogue box 'Activities'
Actual Outcome	Go to dialogue box 'Activities'
Variation	Nil

The idea for doing micro-level verification for the individual participant is same as 'A_All' which has been discussed in appendix 14,so it will not shown in the appendix.